PB-236 146

SURVEY OF LAKE REHABILITATION TECHNIQUES AND EXPERIENCES

WISCONSIN DEPARTMENT OF NATURAL RESOURCES

PREPARED FOR
UPPER GREAT LAKES REGIONAL COMMISSION

1974

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ABSTRACT

Excessive eutrophication of lakes is a serious international problem. There has been a great need for a comprehensive information source usable in developing future rehabilitation/protection programs. This state-of-the-art review represents an attempt to delineate the accomplishments of lake restoration-related activities worldwide. Information was acquired through an extensive mail survey (about 3,000 entries), cooperation of several international journals/newsletters, and a systematic literature search including foreign as well as domestic materials. The contents of this report consist of five major divisions: 1) identification, description and present utility of the various techniques, 2) compilation and description of individual past and/or ongoing restoration experiences (almost 600 accounts), 3) project methodology, 4) name and address of people providing pertinent information (over 300 respondents), and 5) literature references (more than 900 documents).

PREFACE

This report is in part a natural outgrowth of a diversified lake rehabilitation program undertaken by the Inland Lake Demonstration Project, a cooperative effort of the University of Wisconsin and the Department of Natural Resources, funded by the Upper Great Lakes Regional Commission. Since its inception in May 1968, the Project has had a major objective, the demonstration of ways to protect, manage, and rehabilitate lakes. Lake restoration experiments and studies have been conducted by an interdisciplinary team which increasingly recognized the need for a status report on lake rehabilitation and an international inventory of past and ongoing experiences. Aided by a grant from the U. S. Environmental Protection Agency, this report is an attempt to meet that need.

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BIBLIOGRAPHIC DATA SHEET

1. Report No.

2.

PB 236 146

4. Title and Subtitle

SURVEY OF LAKE REHABILITATION TECHNIQUES AND EXPERIENCES
Technical Bulletin No. 75, Dept. of Natural Resources, Univ. of Wisconsin, Madison, Wisc.

5. Report Date
1974

6.

7. Author(s) Dunst, Born, Uttormark, Smith, Nichols, Peterson, Knauer, Serns, Winter, and Wirth

8. Performing Organization Rept. No.

9. Performing Organization Name and Address
A Cooperative Effort of the University of Wisconsin and the Department of Natural Resources, Madison, WI

10. Project/Task/Work Unit No.

11. Contract/Grant No.
R802242

12. Sponsoring Organization Name and Address
Upper Great Lakes Regional Commission and partly funded by U.S. Environmental Protection Agency

13. Type of Report & Period Covered Final
May 1968 to 1974

14.

15. Supplementary Notes
An Inland Lake Renewal and Management Demonstration Project Report

16. Abstracts
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17. Key Words and Document Analysis. 17a. Descriptors
Lake Restoration, Eutrophication, Diversion, Wastewater Treatment, Land-Use Practices, Dredging, Nutrient Inactivation, Dilution, Flushing, Harvesting, Aeration, Biological Control

17b. Identifiers/Open-Ended Terms
State-of-the-Art Review of Lake Restoration

Reproduced by
NATIONAL TECHNICAL
INFORMATION SERVICE
U S Department of Commerce
Springfield VA 22151

17c. COSATI Field/Group

18. Availability Statement Russell C. Dunst, Dept. of Natural Resources, Southern District Headquarters, 3911 Fish Hatchery Road, Madison, WI 53711

19. Security Class (This Report)
UNCLASSIFIED

20. Security Class (This Page)
UNCLASSIFIED

21. No. of Pages
183

22. Price
5.50

FORM NTIS-35 (REV. 3-72)

USCOMM-DC 14952-P72

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SURVEY OF LAKE REHABILITATION TECHNIQUES AND EXPERIENCES

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Technical Bulletin No. 75
DEPARTMENT OF NATURAL RESOURCES
Madison, Wisconsin
1974

INTRODUCTION

Many lakes throughout the world are undergoing accelerated aging (eutrophication) due to man's activities. The resultant problems–prolific weed growth, nuisance algal blooms, deteriorating fisheries, impaired water quality, and sediment infilling–pose a serious threat to the utilization of these lakes. International concern has stimulated considerable research on the nature and causes of the lake aging process, including the development of various control techniques. Although lake degradation and its causes have received substantial attention and some lake rehabilitation* approaches have been described (e.g. Björk 1972a; Boyter and Wanielista 1973; Committee on Government Operations, U. S. House of Representatives 1967; Ketelle and Uttormark 1971; Lee 1970a; National Academy of Sciences 1969; Seppänen 1973; Stewart and Rohlich 1967; Tenney et al. in prep.; Thomas 1965; Vollenweider 1968), there is presently great need for a compilation of information which thoroughly documents the broad spectrum of lake restoration-oriented activities. An initial examination of lake rehabilitation approaches was prepared by the U. S. Environmental Protection Agency (1973) pursuant to legislative mandate. This report is intended to complement that work, as well as to provide a comprehensive survey of past and ongoing studies. It is an attempt to review the existing state-of-the-art in order to help establish a sound base for future lake-renewal-related programs (research and operational).

Approaches to lake restoration fall into two general categories: (1) methods to limit fertility and/or sedimentation in lakes and (2) procedures to manage the consequences of lake aging. Nutrient or sediment limitation techniques treat underlying causes of lake problems. In contrast, techniques for managing the consequences of lake aging are cosmetic in nature. They enhance the usability of lakes without controlling the source of degradation. Many techniques used in lake restoration do not readily fall into a single category, as for example, biotic harvesting, which affects both species population directly (managing a consequence) and nutrient content within a lake. But there are major differences in the practical and theoretical considerations inherent in maximizing one effect over the other. The organization of this report is based on the primary intent of a technique's use. Some techniques, therefore, appear in more than one section.

Fertility and sedimentation in lakes can be limited by reducing the amount of nutrients and sediment that flow into them, chiefly through wastewater treatment, diversion, land use practices, treatment of inflow, and product modification. Other limitation techniques can be used within a lake to inhibit nutrient recycling or to accelerate nutrient outflows. Available methods include dredging, nutrient inactivation/precipitation, dilution/flushing, biotic harvesting, selective discharge, sediment exposure and desiccation, and lake bottom sealing. In addition, various physical, chemical, and biological approaches are available for managing the eutrophic environment without treating the original source of degradation (e.g. aeration/circulation, manipulation of water levels, use of biocides, introduction of pathogens, and many others).

There are many difficulties associated with remedial efforts. Lakes are complicated ecosystems and the ability to predict the response of lake systems to various treatments is as yet limited. Moreover, each lake has its own "unique personality", which frustrates attempts to transfer results from one lake to another that appears to have similar problems. There are also time constraints associated with lake renewal programs. The public wants prompt action and immediate results. This is seldom possible. A certain amount of pre-treatment information is required to formulate a well-founded remedial program. Natural variation may mask initial changes brought about by a lake treatment so that years may be required to demonstrate that real changes have taken place. The economics of a particular lake renovation effort can also affect the choice of treatment alternatives, but this constraint may exist only because requisite equipment and/or experience is lacking. In spite of these difficulties it is possible to develop some guidelines for the renewal of lakes. Encouraging results are being produced by markedly increased research and experimentation on lake rehabilitation.

Subsequent sections of this report will assess the existing state of knowledge concerning each technique. The specific objectives are twofold: (1) identification and general description of available lake restoration techniques, and (2) compilation and description of past and ongoing experiences with each technique.

Although successful rehabilitation of a particular lake will often require the integrated implementation of several techniques due to the numerous interacting biotic and abiotic variables within an ecosystem, the several lake restoration approaches are discussed individually. The content of Part One is applicable to all freshwater lakes, natural and man-made, ranging in size from small ponds to inland seas, although differences in size and type, climatic variables, etc. will of course affect the applicability of particular restoration techniques to specific situations.

The compilation of individual lake restoration experiences (Part Two) primarily contains well-documented investigations focusing directly on lakes with eutrophication/sedimentation problems. Nevertheless, some studies lacking that focus have been included; those can be categorized as: (a) poorly documented, or incomplete studies involving innovative ideas, (b) substantive programs in a preliminary phase, and (c) tangential studies deemed of some value to workers in lake restoration. In addition, although fish manipulation studies conducted on noneutrophic lakes were omitted whenever possible, lake descriptions were often vague and some inappropriate studies are likely retained in this section.

The organization of Part Two also requires some explanation. The information was presented in a standardized manner and the various activities were categorized into tabular form in order to maximize the utility of this section. The sources of information were numerous for many of the individual projects and were sometimes conflictory. This fact, together with the author's lack of personal familiarity with most of the projects, may have resulted in some inaccuracies.

Parts Three, Four and Five–methodology, respondents, and bibliography, respectively–are relatively straightforward and need little explanation. The respondents supplied information primarily between late November, 1972 and April, 1973, although some communications obtained as late as December, 1973 were also incorporated into the report. If desired, any of the bibliographical references in Part Five can be secured at nominal cost from the Information Services Division of the Engineering and Physical Sciences Library, University of Wisconsin, Madison, Wisconsin, USA 53706.

**Rehabilitation* is defined here as the manipulation of a lake ecosystem to effect an in-lake improvement in degraded or undesirable conditions. In this report the terms *rehabilitation, renovation, renewal* and *restoration* are used synonymously.

PART ONE:
SYNOPSIS OF LAKE REHABILITATION TECHNOLOGIES

LIMITING FERTILITY AND CONTROLLING SEDIMENTATION

The objective of limiting fertility in lakes is to reduce the excessive and undesirable growth of algae and rooted aquatic vegetation. It is not the fertility per se which is of concern, but rather the associated plant growth which results in objectionable consequences in some lakes. Unless environmental conditions such as light or temperature are limiting, aquatic plants respond to the quantity of nutrients made available to them. For the purposes of our discussion, therefore, it is convenient to focus on the nutritional requirements of aquatic plants and to identify methods by which the availability of nutrients can be reduced. Nutrient control schemes have thus far been directed primarily at nitrogen and phosphorus.

The availability of these nutrients encompasses several considerations. Chemical form is important. Many algal species can utilize both ammonia and nitrate nitrogen and some blue-green algae can use molecular and nitrite nitrogen as well. Orthophosphate is generally considered to be the form of phosphorus most readily utilized by plants. In addition to being in a usable chemical form, nutrients must also come into contact with the plants at a time when they can be used. To minimize the effects of excessive fertility, the object is, therefore, to restrict the quantities of nutrients which reach the *photic zone* of a lake in a *biologically available form* at a *time* when they can contribute to the undesirable growth of aquatic plants.

Limiting the fertility of lakes is often considered synonymous with curbing the nutrient influx. When viewed in the above context, however, it is clear that similar results can also be obtained by disrupting or phasing the flow of nutrients within the lake proper. Lake rehabilitation schemes have been developed which take advantage of a variety of these options to limit lake fertility.

Curbing Nutrient Influx

Nutrient influx provides the driving force which maintains the fertility of lake systems. Internal recycling tends to perpetuate nutrient-rich conditions, but since this process is not 100% efficient, system losses must be compensated for by nutrient additions from external sources or the fertility of the system will be reduced.

It is generally agreed that the most desirable long-term lake management approach is to control the influx of nutrients, but there is considerable disagreement regarding the selection of nutrient sources to be controlled, the method for control, and the benefit to be gained. Current technology permits the identification of significant nutrient sources and it is possible to estimate the annual nutrient influx contributed by each of the various sources. The intricate, internal nutrient pathways are far too complex to expect that simple relationships can be established between the influx of nutrients and undesirable plant production or other parameters of lake quality. Yet sufficient information does exist to provide some guidelines for designing and assessing nutrient abatement programs.

On the basis of water analyses from 17 Wisconsin, USA, lakes, Sawyer (1947) suggested that if, at time of spring overturn, concentrations of inorganic phosphorus and inorganic nitrogen (ammonia plus nitrate nitrogen) exceeded 0.01 and 0.3 mg/l respectively, a lake may be expected to produce excessive growths of algae or other aquatic plants. Vollenweider (1968) conducted a statistical analysis of data reported by Thomas (1953) and concluded that the critical levels suggested by Sawyer were generally borne out by the condition of lakes in Central Europe.

The critical concentrations suggested by Sawyer, although not to be construed as rigid lines of demarcation, do provide target values for lake renewal efforts. However, it is difficult to relate these values directly to reductions in nutrient input, because the relationship between nutrient influx and in-lake nutrient concentrations is not clear.

At this time, the best available guidelines for relating the nutrient influx to water quality in lakes are provided by criteria presented in Table 1. These results are based on data from 30 lakes (12 from Central Europe, 10 from North America, and 8 from Northern Europe) and must be considered provisional, subject to confirmation or modification by subsequent work. Some adjustment does, in fact, appear necessary for shallow lakes. Nutrient loading studies conducted on Florida, USA lakes—mean depth near 2 m—indicated that these waters are able to withstand much higher loadings on a lake volume basis ($g/m^2/yr$) than suggested by Table 1 (Shannon and Brezonik 1972). The establishment of critical loading levels are essential to provide criteria for assessing the need for nitrogen and phosphorus abatement and the potential benefits to be realized in specific situations.

Specific loading levels provide a basis for judging the degree to which nutrient influx must be curbed to achieve more desirable conditions in lakes, but they give no information regarding the rate of improvement that might be expected as a result of reducing loadings. Several analyses have been conducted that relate the rate of response to the hydraulic residence time of a lake (Rainy 1967). In models of this type, lakes are assumed to act as completely mixed systems in which the nutrient content is reduced solely by discharge through the outlet. Reduced nutrient inputs result in an exponential decrease in in-lake concentration; 95% of the ultimate reduction will be achieved in three hydraulic residence times. These models are most appropriately applied to conservative substances and have serious deficiencies when applied to nonconservative substances such as plant nutrients.

An important modification in approach was presented by Vollenweider (1969), Megard (1971), and Sonzogni and Lee (1972). In this model, complete mixing was also assumed, but nutrient loss to sediments was included in addition to loss through the outlet.* This modification is most applicable to phosphorus because, unlike nitrogen and carbon, the phosphorus cycle in lakes does not include a gas phase. The phosphorus retention time defined by the model is, in most situations, considerably shorter than the hydraulic residence time and the predicted rate of lake response is an exponential function of the shorter phosphorus retention time. Lee (1972) applied this model to Lake Michigan and estimated that 95% improvement would be achieved in 15-20 years rather than in 90 years as estimated from the hydraulic residence time model. Phosphorus retention times for selected lakes are given in Table 2.

Both of the models described above are admittedly crude, but the latter is more realistic and fortunately gives a more optimistic outlook for lake renewal endeavors. Improvements in the predictive capabilities of these models, and therefore the attainment of satisfactory results accruing from lake restoration programs, are still contingent upon a better understanding of sediment-water transport processes.

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*Considerable amounts of nutrients are "lost" to bottom sediments; lakes are often considered to more closely approximate nutrient "traps" than completely mixed flow-through reactors.

Wastewater Treatment

Wastewater treatment at both municipal and industrial sources is perhaps the most widely used technique for reducing the nutrient loads of waterways, although nutrient removal for lake protection or improvement is probably a major objective in only a minority of situations. Advanced treatment processes designed for improved removal of phosphorus and nitrogen have been developed and increasing pressure is being applied to utilize these systems (Daniels and Parker 1973; Adams 1973). In the United States alone, more than 12,500 treatment plants with 25,000 outfalls have been identified (Payne 1972). Only a minority of these discharge to lakes, but the impact is nevertheless significant. Okun (1971) estimated that 15% of the population of the United States contribute wastewaters that could potentially be promoting the eutrophication of lakes and estuaries. This estimate did not include contributions from septic tank systems. The contribution of municipal and industrial wastewaters to the nutrient budget of several lakes is given in Table 3.

Many wastewater treatment systems presently in operation were designed primarily to reduce BOD (biological oxygen demand) to protect the oxygen resources of the recipient water body. Although some nutrient removal does occur, the efficiency is generally low–about 5-15% removal results from primary treatment and conventional activated sludge systems typically remove about 30-50% (Convery 1970). Awareness of eutrophication problems related to nutrient content of wastewaters and treatment plant effluents has focused increased attention on the development of new processes that remove nutrients more effectively. Upgrading of treatment systems by advanced waste treatment methods usually consists of modifying the existing process or adding a tertiary step to the conventional plant.

A thorough review of nutrient removal systems is beyond the scope of this report. Instead, several processes are identified and general ranges of removal efficiencies are given (Table 4). The principles of these processes and some of their inherent advantages and disadvantages have been described by Rohlich and Uttormark (1972). Current technology in the area of nutrient removal processes is sufficiently advanced so that practical systems can be designed, constructed and operated. Costs, although largely dependent on existing facilities, are also reasonably well known. But the net effect of such treatment in any given instance is uncertain, thereby making it difficult to ascertain if the improvement in receiving bodies is likely to be commensurate with cost.

At the present time there are no documented cases of lake improvement resulting from wastewater treatment where the discharge of the highly treated effluent to the lake was continued. Although the efficacy of this technique has not been proven, several demonstrations are underway. Three examples of well-documented programs are:

(1) Lake Michigan, USA

In 1968, the states bordering on Lake Michigan adopted regulations requiring the removal of at least 80% of the total phosphorus entering municipal wastewater treatment plants that discharge to the lake or its tributary streams. This was to be accomplished by December 1972.

According to Zar et al. (1972) wastewater sources contribute about 6 x 10^6 kg of phosphorus per year to Lake Michigan. Lee (1972) considered this input to be about 73% of the total contribution and Bartsch (1968) estimated that about 66% of the total phosphorus loading of the lake originates from industrial or municipal sources. Using either of these estimates, an 80% reduction in phosphorus from wastewaters will result in a 50-60% reduction of the total phosphorus influx to the lake.

TABLE 1. Specific Nutrient Loading Levels for Lakes (Expressed as Total Nitrogen and Total Phosphorus in g/m^2/yr)*

Mean Depth up to:	Permissible Loading, up to: N	Permissible Loading, up to: P	Dangerous Loading in Excess of: N	Dangerous Loading in Excess of: P
5 m	1.0	0.07	2.0	0.13
10 m	1.5	0.10	3.0	0.20
50 m	4.0	0.25	8.0	0.50
100 m	6.0	0.40	12.0	0.80
150 m	7.5	0.50	15.0	1.00
200 m	9.0	0.60	18.0	1.20

*From Vollenweider (1968).

The total phosphorus influx to Lake Michigan, prior to achievement of the 80% reduction from wastewater sources, was approximately 8.2 x 10^6 kg/yr (Lee 1972). Converted to a specific loading, using the total surface area of the lake (5.8 x 10^{10}m^2), this influx amounts to 0.14 g P/m^2/yr, or 0.06 g P/m^2/yr after the improved wastewater treatment facilities were in operation. Specific loadings, both before and after remedial management, were well below the permissible phosphorus loading of 0.3 g P/m^2/yr suggested by Vollenweider (1968). However, the entire surface area of the lake was used in computing these values. This approach is, therefore, somewhat misleading for a lake as large as Lake Michigan because the lake consists of several, not readily definable, water masses which are affected by eutrophication to differing degrees. Assessment should more properly be based on changes in local conditions, not on the lake as a whole.

A considerable number of studies are currently underway that, when completed and assessed collectively, will provide solid documentation of the changes in Lake Michigan that result from the removal of phosphorus from wastewaters.

(2) Lake Shagawa, Minnesota, USA

Since 1966, a study has been underway to evaluate the effectiveness of advanced wastewater treatment at Ely, Minnesota (pop. 5,500) as a means of reversing eutrophication in Lake Shagawa.

Nutrient budget studies on Lake Shagawa have shown that about 80% of the total phosphorus and 25% of the total nitrogen entering the lake are contributed by the municipal effluent from Ely (Malueg, pers. comm.). Completion of the improved treatment facilities will not affect the nitrogen influx but phosphorus will be reduced to less than 1% of the present loading. Although the phosphorus influx from Ely may be virtually eliminated, other sources are estimated to contribute 0.15 g P/m^2/yr, which is slightly in excess of the suggested permissible loading of 0.10 g P/m^2/yr for lakes with mean depths less than 10m.

The lake and the treatment facility have undergone intensive study by the U. S. Environmental Protection Agency and, when completed, will provide a quantitative evaluation of this lake renewal venture.

(3) Lake Leman, France and Switzerland

In France and Switzerland an effort has been underway since the mid-1960s to reduce the nutrient influx to Lac Leman (Geneva) by improved wastewater treatment. The plan is to equip municipalities initially with mechanical and biological systems and later to upgrade these facilities for chemical removal of phosphorus. In 1968, 44% of the permanent, near shore residents were served by treatment plants and the entire program is scheduled for completion in 1976. Laurent et al. (1970) reported studies which document

TABLE 2. Comparison of Hydraulic and Phosphorus Residence Times for Selected Lakes

Lake Name	Hydraulic Residence Time (yr) T_H	Phosphorus Residence Time (yr) T_P	$\frac{T_P}{T_H}$	Reference
Washington, USA	3.2	0.8	0.25	Megard (1971)
Minnetonka, USA	25.0	0.9	0.04	do
Sebasticook, USA	3.5	1.4	0.40	do
Norrviken, Sweden	0.6	0.3	0.50	do
Clear, USA	6.0	2.0	0.33	do
Mendota, USA	4.5	0.9	0.20	Sonzogni and Lee (1972)
Michigan, USA	30.0	6.0	0.20	Lee (1972)

TABLE 3. Contributions of Municipal and Industrial Wastewater to Nutrient Budget of Lakes

Lake	Reference	Phosphorus (%)	Nitrogen (%)
Mendota, USA	Lee (1970b)	36	10
Ontario, USA & Canada	International Joint Commission (1970)	57	30
Michigan, USA	Bartsch (1968)	66	
Erie, USA & Canada	International Joint Commission (1970)	70	35
Potomac River Estuary, USA	Jaworski and Hetling (1970)	87	51
Waubesa, USA (before diversion)	Sawyer (1947)	88	75
Shagawa, USA	Malueg (pers. comm.)	80	25

TABLE 4. Comparison of Nutrient Removal Processes for Domestic Waste*

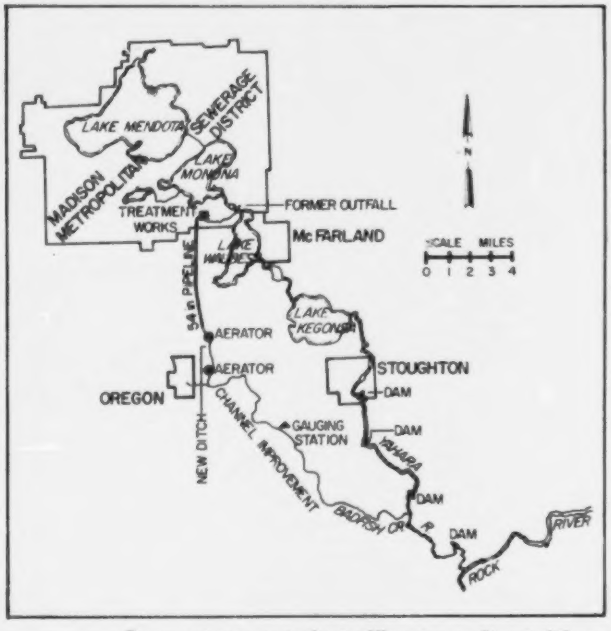
Process	Removal Efficiency (%) Nitrogen	Phosphorus
Ammonia stripping	80-98	
Anaerobic denitrification	60-95	
Algae harvesting	50-90	varies
Conventional biological treatment	30-50	10-30
Ion exchange	80-92	86-98
Electrochemical treatment	80-85	80-85
Electrodialysis	30-50	30-50
Reverse osmosis	65-95	65-95
Distillation	90-98	90-98
Land application	varies	60-90
Modified activated sludge	30-50	60-80
Chemical precipitation		88-95
Chemical precipitation with filtration		95-98
Sorption		90-98

*From Eliassen and Tchobanoglous (1969).

conditions existing in Lac Leman prior to the renovation program. Data showed trends of decreasing oxygen concentration in the hypolimnion—anaerobic conditions were not reached but dissolved oxygen levels were reduced to approximately 35% saturation. From 1962 to 1967, the average total phosphorus concentration increased from 15 to 25 μg/l. Nitrate concentrations in the hypolimnion increased from 0.23 mg N/l in 1957 to 0.39 in 1968. Biological investigations have also documented an increase of blue-green algae. Despite the partial implementation of the wastewater treatment program, conditions in the lake continue to decline.

Diversion

Diversion is defined here as the rerouting of waters outside of a lake's drainage basin; other types of treatment (e.g. wastewater purification) may or may not accompany this lake renovation technique. Diversion without treatment has, however, been severely criticized because of the effects it may have on recipient waters. Although the effects of diversion on lakes have been documented in relatively few instances, it is coming increasingly into practice and additional documentation is forthcoming. Two examples illustrate past experiences:



Sewage treatment plant effluent was diverted from Lakes Waubesa and Kegonsa (Madison lakes), Wisconsin, USA in 1958. From Lawton (1961).

Lake Washington, Washington, USA. The best known and documented case of lake improvement resulting from diversion is Lake Washington. Changes that occurred in this lake prior to diversion were described by Edmondson (1961), Edmondson et al. (1956), and Anderson (1961). The response to reduced nutrient influx has been reported by Edmondson (1966, 1969, 1970, 1972 a and b). Mean winter concentrations of phosphorus were reduced to 28% of pre-diversion values and chlorophyll was reduced by a comparable amount. Secchi disk transparency in summer increased from 1.0 to 2.8 m. Nitrogen levels in the lake were reduced about 20% from pre-diversion levels. This finding was in agreement with nutrient budget data, which indicated that sewage effluents contributed only 12% of the total nitrogen, but 56% of the phosphorus. Phosphorus reduction was identified as the key factor responsible for the water quality improvement.

Lakes Waubesa and Kegonsa (Madison Lakes), USA Lake Waubesa (Madison, Wisconsin) receives the discharge from Lake Monona and releases water into Lake Kegonsa. Sewage treatment plant effluent was discharged into Lake Monona or its outflow until 1958, when a diversion channel began operation to transport the treated sewage away from these lakes.

Detailed studies of the Madison, Wisconsin lakes by Sawyer et al. (1943, 1945) were prompted by the occurrence of tremendous algal growths. Sawyer et al. found, after measuring the various sources of nutrients, that inorganic nitrogen and soluble phosphorus appeared to be critical substances with respect to algal blooms in lakes. Diversion of the Madison Sewage System effluent was expected to cause a significant reduction in the frequency and intensity of algal blooms but not their elimination.

Removal of the effluent resulted in an estimated decrease in the inorganic nitrogen and soluble phosphorus inflow to Lake Waubesa of 75 and 86%, respectively. Three winters after diversion the soluble phosphorus—as compared to pre-diversion levels—was about 70% lower for Lake Waubesa and 30% lower for Lake Kegonsa. Initially the algal population in Lake Waubesa consisted of over 99% noxious blue-green species. Within one year after diversion these species were reduced by 25-75%, although the total quantity of algae remained the same. The increased species diversity was still present in 1972. A diverse algal population existed in Lake Kegonsa before and after diversion. The effects of this diversion have been discussed by Lawton (1961), Fitzgerald (1964, 1965), Stewart and Rohlich (1967), and Sonzogni and Lee (1972).

In summary, the technique of diversion is being applied in a sizable number of situations throughout the world but at present there is insufficient information available to permit results to be predicted consistently. Nutrient budget information, perhaps the most important data, is lacking in most instances. Although the applicability of this technique is restricted by physical considerations and lake conditions have not always improved following diversion, results to date have generally been encouraging.

Land Use Practices

Indirect or nonpoint sources of pollution, which are incidental to land uses throughout the drainage basin of a lake, are a major cause of lake degradation. Man's many uses of the land contribute polluting substances to water bodies (Bullard 1966). The nutrient flux of lakes may be markedly increased by land alterations. The same is true for sediment inflows; on a volume basis, sediment is the biggest pollutant of lakes and waterways (U. S. Environmental Protection Agency 1973). Sedimentation in reservoirs and the associated losses in storage capacity represent major problems (U. S. Department of Agriculture 1963).

Land development activities —urban and suburban building and highway construction—threaten nearby water bodies with sediment (U. S. Environmental Protection Agency 1971a; Leopold 1968, 1973). Logging activities can dramatically increase sediment and nutrient concentrations in runoff from affected drainage basins (Fredriksen 1970; Likens et al. 1970; Bullard 1966). Agricultural land uses can result in significant contributions of both sediments and nutrients (U. S. Environmental Protection Agency 1971b; U. S. Department of Agriculture 1971; Soil Conservation Society of America 1971; Wellrich and Smith 1970). Table 5 suggests the expected contributions of phosphorus and nitrogen from several categories of land use.

Efforts to limit nutrient and sediment inputs from lands within drainage basins, for lake protection as well as rehabilitation, have followed two general lines: (1) structural and land treatment measures to intercept nutrients and sediments before they reach water bodies, and (2) regulatory approaches, particularly land use controls, to restrict uses with direct or indirect pollution potential or effects. The first approach is typified by the activities of the Soil Conservation Service, U. S. Department of Agriculture (Simms 1970). This agency is involved with land-use conservation programs, largely on rural lands. Programs have been promoted by extensive educational efforts and facilitated by providing technical assistance and cost-sharing incentives. The second approach is illustrated by shoreland protection programs such as Wisconsin's (USA) joint state-local regulatory zoning of shorelands around lakes (Yanggen 1971; Busselman and Callies 1971; Kusler 1970; Wisconsin Department of Natural Resources and University Extension 1967) and Iowa's (USA) erosion control laws (Boyce and Beer 1973).

Sediment and Nutrient Control Measures. The most fundamental concept of sediment control is prevention of soil erosion (U. S. Department of Agriculture 1963). Over the years several agricultural conservation practices have been developed to keep soil on the land. These practices include terracing, grassed waterways, contour farming, conservation cropping systems, crop residue management, and creation of shelterbelts. Erosion and sediment control measures applicable to land development and highway construction can be divided into two categories—mechanical and vegetative (U. S. Department of Agriculture 1970a). Mechanical measures are used to intercept, divert, retard, or otherwise control runoff and include such practices as land grading, bench terracing, construction of diversion and waterway stabilization structures and installation of sediment basins (e.g. Swerdon and Kountz 1973). Vegetative measures include the use of mulches and temporary and permanent cover crops. Erosion control and stabilization of lake shorelines can be accomplished by both structural and vegetative means (U. S. Army Corps of Engineers 1971; U. S. Army Coastal Engineering Research Center 1966). Additional information on land treatment practices to avoid or abate sediment problems is given elsewhere (U. S. Environmental Protection Agency 1972; National Association of Counties Research Foundation 1970).

There are many examples of erosion and sediment control programs in the drainage basin and around the shorelines of large and small lakes. Rarely, however, does detailed technical documentation of the effectiveness of control and/or abatement programs exist (see Part Two).

Because sediment is not only a physical pollutant but serves as a transport agent for nutrients, its control is also a form of nutrient limitation. Nutrients are not only carried by dislodged sediments but are also dissolved in drainage waters. Nutrients in agricultural runoff are derived from native soils, decaying crop residues, organic and inorganic fertilizers applied to the land, and animal wastes. The management and control of agricultural nutrients requires the efficient use of applied fertilizers (i.e. the application of commercial fertilizers and manure at permissible rates under the right climatic and crop growth conditions) and the retention of animal wastes on the land (Loehr 1972).

In the Lake Mendota, Wisconsin, USA drainage basin a pilot project provided Federal cost-sharing for farmers to construct facilities for winter storage of manure (Last 1971). It was estimated that runoff from manured land contributes a major portion of the soluble nutrients to Lake Mendota, although no relationship existed to predict the effects of this planned change in land use practices on the lake. Unfortunately the program was terminated before a significant number of farmers in the drainage basin became participants in the project and the short-term results were demonstrative only of better ways to store and handle manure rather than of the water quality consequences.

Regulatory Approaches. Although land treatments to control sediments and nutrients and thus help restore or protect lake resources have been available, some political jurisdictions have found it necessary to impose regulations requiring adherence to certain land use practices while prohibiting others. Governments at all levels are beginning to incorporate standards and specifications for soil erosion and sediment control in the regulation of land development activities (U. S. Department of Agriculture 1969 and 1970b; Boyce and Beer 1973).

In Iowa, USA laws were passed in 1971 that provide for mandatory soil conservation.

> "Iowa's Conservancy District Act established six conservancy districts in the state and declared soil erosion resulting in siltation damage to be a nuisance. The act also directed the commissioners of each soil conservation district to establish soil loss limits for their district. . .
>
> If erosion exceeds the prescribed limit, an administrative order may be issued stating to what degree erosion exceeds the prescribed limits and directing the responsible individual to reduce erosion to that limit. However, a landowner cannot be required to install permanent conservation practices unless cost-sharing funds equal to 75 percent of the cost are authorized and made available to him" (Boyce and Beer 1973).

TABLE 5. Expected Loss Rates of Nitrogen and Phosphorus From Various Sources (Expressed as g/m^2 of land use area/yr)*

Source	Quantity of Nitrogen	Quantity of Phosphorus
Fertilized area		
Citrus farms	2.24	0.018
Muck farms	0.11	0.135
Pastured area	0.85	0.018
Unproductive cleared area	0.18	0.006
Forested area	0.24	0.008
Urban area	0.88	0.110

*After Shannon and Brezonik, 1972.

And the State of Illinois has considered regulations which prohibit the use of certain types of fertilizers in excess of specified amounts.* A much broader regulatory approach, one concerned with lake protection rather than lake rehabilitation but important in maintaining rehabilitated lakes, is illustrated by the Wisconsin Shoreland Protection Statute. The statute contains provisions authorizing and requiring counties to adopt regulations for shoreland areas. These regulations are designed to control pollution and to protect shoreland amenities.

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*The states of Indiana, Iowa and Minnesota, USA have adopted various kinds of farm animal waste regulations—chiefly aimed at problems related to large feedlot installations.

The purpose of the regulations shall be to further the maintenance of safe and healthful conditions; prevent and control water pollution; protect spawning grounds, fish and aquatic life; control building sites, placement of structures and land uses and preserve shore cover and natural beauty (Wis. Stat., Sec. 144.26).

Although pollution control was only one of several objectives of the law, special consideration was given to developing reasonable restrictions on land uses to effectuate pollution control (Kusler 1970). The Wisconsin scheme, which has since been emulated by other states, sets out zoning, sanitary code provisions and subdivision regulations in a model ordinance for adoption by counties. Zoning is used to prohibit pollution-generating uses on shorelands adjacent to high quality waters, to protect wetlands, to require building setbacks from the shoreline and to restrict vegetation removal to reduce erosion. Subdivision regulations and sanitary codes limit development in areas particularly susceptible to erosion and in areas where the soils preclude adequate onsite waste disposal (Kusler 1970).

The State of Minnesota in its shoreland management program (Minn. Stat. 1969, Chap. 777) has made one notable advance relative to the Wisconsin scheme. Its system provides for the classification of all lakes in the state with different zoning standards for each category of lake (State of Minnesota 1971). The protective (or rehabilitative) land use controls thus broadly reflect lake characteristics, including water quality.

Many lake rehabilitation efforts will require changes in land use practices in a lake's drainage basin in order to slow the process of eutrophication. Techniques exist to limit the influx of sediments and nutrients to a lake. Adoption of conservation-oriented land use practices to augment other lake rehabilitation activities can be achieved by education of landowners, assistance (cost-sharing, preferential tax treatment and other incentive programs) and land use controls. Broad-scope natural resources legislation such as shoreland regulations, generally intended to prevent rather than abate water pollution, includes land use provisions applicable to lake renewal. Of course regulations require continuing administration and enforcement to be effective.

Although some difficult institutional problems remain, the technology for land management to improve the quality of inflows to lakes and hence the lakes themselves exists. Despite this, there is virtually no quantitative documentation of improvements in lake conditions as a result of changes in land use practices. Well-designed research projects of sufficient longevity to furnish meaningful results are needed to demonstrate the efficiency of the various methods.

Treatment of Inflow

The treatment of all or a substantial portion of the inflow has potential as a way of controlling sediment or nutrient additions to a lake. Treatment of the inflowing waters may be justified where: (1) the sources of nutrients or sediment are so diffuse that they cannot be controlled individually and diversion is unacceptable or (2) the economics of abatement preclude small-scale treatment works in favor of a more efficient large-scale system. Any treatment plan must take into account the influence of lake water residence time and the significance of the estimated nutrient loading reduction on the water quality of the lake.

Metal ions can be used to remove dissolved nutrients (particularly phosphorus) as well as suspended solids. Ions

Lake Needwood, Maryland, USA. Flocculant was added to two of the tributaries. After two years of treatment, some 5,600 cubic yards (about 4,300 cubic meters) of flocculated sediment were dredged from this forebay. Photo furnished by McNaught (pers. comm.).

such as aluminum, calcium, or iron, which form low solubility phosphate compounds and/or provide an active phosphate-sorption site and a settleable floc, have been used extensively in water and waste treatment processes. Iron (III) was employed to remove both dissolved and suspended forms of phosphorus from the entire inflow to Wahnbach Reservoir, West Germany (Bernhardt et al. 1971) and also for phosphorus removal from the Rhine River in the Netherlands (Peelen 1969, and pers. comm.). Other materials having potential for general or specific nutrient removal include iron exchange agents and high-phosphate-sorption capacity solids (e.g. clays, zeolites, flyash).

Aeration and mixing systems have also been installed in influent waters to lakes. Cascade and air injection facilities were operated to oxygenate a river flowing into Lake Taneycomo, Missouri, USA to prevent fish kills in the lake (Water Spectrum 1972). The potential effects of oxygenation are stripping of dissolved gases (e.g. N_2, CO_2, NH_3, H_2S), oxidation of reduced elements (e.g. Fe, Mn, S)and organic compounds, and flotation of suspended solids. Ambient air or pure oxygen may be used in a variety of processes to achieve satisfactory results (Speece 1969; Murro and Yeaple 1971).

Some additional procedures that appear to have potential but which have not yet been applied in lake restoration projects involve: (1) biotic harvesting. Nutrients can be concentrated by growing organisms in the upstream waters. Some aspects of biotic harvesting for nutrient removal are explored later (p. 14); (2) shading of streams and channelization of the lake bottom. The effects of nutrient loading might be minimized by causing the inflow to disperse within the lake below the epilimnion; and (3) metal ion injection into upgradient aquifers. This might significantly reduce the nutrient loadings to lakes receiving high phosphorus ground waters.

Although encouraging results have been noted with the use of several approaches to the treatment of inflow, the technology of actual implementation is still imprecise due to the relatively small number of experiences. Presently the biggest difficulty centers on the widely varying flow rates and water quality that commonly occur in lotic environs. Nevertheless as the demand for high quality lakes increases, the need for more sophisticated lake restoration approaches will increase and past successes indicate that inflow treatment techniques merit further development.

Product Modification

Certain commercial products are capable of influencing the rate of eutrophication. Detergents and chemical fertilizers in particular are used in large quantities, have a high phosphorus content and are readily transported into lake systems. Much discussion has centered around the possibility of reformulation using a lower concentration of phosphorus. Most of the attention has thus far been directed at detergents (Committee on Government Operations, U. S. House of Representatives 1970a, 1970b, and 1972; Committee on Commerce, U. S. Senate 1972).

Rukeyser (1972) points out the importance of detergents as a phosphorus source:

> "In many lakes, as much as 70 percent of the incoming phosphorus is thought to flow from municipal sewage plants. Of the phosphorus contained in sewage, 40 to 70 percent often comes from phosphate detergents—and nearly all of these are manufactured by just three corporations. In sum, the simple expedient of forcing three companies to change their product formulas might eliminate close to 50 percent of all the phosphorus going into some lakes."

In the case of lakes also receiving the effluent from significant numbers of malfunctioning individual septic systems, presumably the reduction would be even more dramatic.

In response to the need for change, government research and a voluntary detergent industry program were initiated to find suitable phosphorus substitutes (National Industrial Pollution Control Council 1970). As a result of these efforts, several effective phosphate-free detergents have been formulated with substances that are relatively safe and nonpolluting (Reilich 1972). Concurrently the use of phosphate detergents has been restricted or banned in several areas. Local or state regulations that limit the phosphorus content or prohibit the use of phosphorus detergents have been enacted in many parts of the United States (American Chemical Society 1973a). In Sweden the phosphorus content of detergents is limited nationwide (Carlsson, pers. comm.). Several studies are now evaluating the effects of product modification control measures upon particular lakes. Initial findings have noted in-lake reductions of phosphorus concentrations and nuisance algal populations (Onondaga Lake, New York, USA; Murphy et al. 1973).

In-Lake Schemes to Accelerate Nutrient Outflow or Prevent Recycling

Curbing excessive nutrient and sediment inputs is the most effective and desirable long-term solution to the problems of lake degradation, but the time-span required to implement input control measures, reinforced by the public's demand for "immediate" results, has stimulated the development of several schemes designed to limit the availability of nutrients already present in the lake ecosystem. In-lake nutrient control techniques can accelerate the recovery of a lake from excessive fertilization and although they are undoubtedly most effective when preceded by a reduction in external loading, used alone they can also provide relatively rapid but usually only temporary relief from the effects of overfertilization.

Nutrient pathways in lakes are complex and poorly understood. The biological and chemical interactions that are critical to nutrient exchange processes are dependent on a host of environmental variables. Thus, the role of the sediments, which represent the largest source of potentially available nutrients in most eutrophic lakes, remains uncertain. Although considerable effort has been expended in an effort to determine the dynamics of sediment-water nutrient interchange, the findings are inconclusive.

It seems likely that sediments act as a buffer, removing phosphorus and nitrogen from lake water when the concentration is high and releasing nutrients when the concentration is low (Keeney 1972 and 1973; Lee 1970c; Latterell et al. 1971; Harter 1968), but the issue is complicated by thermal stratification and the periodic fluctuations between aerobic and anaerobic conditions in the bottom waters of eutrophic lakes. Brezonik and Lee (1968) found that the net flow of nitrogen in Lake Mendota, Wisconsin, USA, is to the sediments and a similar movement is indicated for phosphorus in most lakes (Porcella et al. 1971), but the timing of nutrient release and uptake may tend to support algal blooms (Stumm and Leckie 1970). In addition, the entire nutrient equilibrium may shift in the direction of the water in lakes in which external nutrient sources have been reduced or eliminated, thereby delaying the recovery period for a long time (Frink 1967; Gumerman 1970; Hynes and Greib 1970).

The pathways and rates of interchange between the biotic links in the nutrient cycle are just as uncertain as the dynamics of the sediment-water reaction. Estimated turnover rates of soluble inorganic phosphorus in the trophogenic zone are several orders of magnitude greater than the turnover rates in the profundal region and the rapidly changing environmental conditions further complicate application of basic limnological research to lake management schemes. A thorough understanding of the importance of external nutrient input as opposed to internal nutrient recycling is of prime importance in understanding and controlling eutrophication. There is an urgent need for knowledge regarding the rates and directions of nutrient movement. Nevertheless, numerous in-lake control techniques have been developed; these techniques are directed at the sediments, the water and the biota itself. Many of these techniques can result in at least temporary improvements in the trophic status of lakes and the net effect is desirable even though the internal interactions are incompletely understood.

Dredging for Nutrient Control

Inasmuch as lake sediments represent a potential nutrient source, sediment removal is often advocated as a means of reversing or retarding eutrophication. Although it is typically undertaken simply as a cosmetic approach to lake improvement (p. 19), dredging may also improve the trophic status of a lake by uncovering a stratum that does not contain or release appreciable quantities of nutrients.

The role of sediments in determining the overall productivity of surface waters is of prime importance in evaluating dredging as a nutrient control measure. There is little evidence to suggest that phosphorus, and probably nitrogen as well, moves from deep lake sediments at a rate fast enough to support substantial algal growth at a distance of more than a few meters from the interface. Stumm and Leckie (1970) calculated a maximum diffusional release rate for sedimentary phosphorus of 100 mg P/m^2/yr. Based on Vollenweider's analysis (Table 1), this would represent a low phosphorus loading rate for a lake with a mean depth greater than 10 m, but would be close to a dangerous loading rate for a lake with a mean depth of 5 m.

In shallow, unstratified lakes, the rate of sedimentary phosphorus release is probably considerably greater than that calculated for diffusion due to both biological and physical disturbance at the mud-water interface. Haertel (1972) found that the sediments contributed a major portion of the nutrient load in shallow lakes with substantial wind-induced circulation to the sediment surface. The nutrient contribution of shallow sediments may be closer to that suggested by Porcella et al. (1971), who observed a release rate resulting from algal growth and anaerobic fermentation of 20 to 200 times that calculated by Stumm and Leckie.

A significant reduction in the nutrient contribution from shallow sediments may be possible if a nutrient-poor layer can be exposed. The dredging program at Lake Trummen, Sweden–surface area of 1 km^2 and a mean depth of only 1.1 m–is an outstanding example of this approach (Björk et al. 1972). The uppermost layer of sediments, which had been deposited over a 20-year period of sewage inflow, was continuing to release nutrients to the overlying lake water after external inputs were eliminated. About one meter of sediment was dredged from the lake and results to date indicate that the project has been highly successful. The achievements of this restoration attempt have stimulated similar dredging proposals and activities elsewhere.

In other lakes with comparable histories of cultural eutrophication there is, however, no guarantee that the available nutrient content of the sediments decreases with depth. Stumm and Leckie (1970) pointed out that the phosphorus concentration in lake sediments may bear little relationship to the trophic history of a lake. Iron, calcium, aluminum and fine-grained inorganic sediments can effectively bind phosphorus, and cultural disruption of their sedimentary cycles can lead to paradoxical nutrient profiles. Furthermore, sedimentary phosphorus concentrations may only reflect the binding capacity of the sediments and not the levels in the overlying water (Williams et al. 1970; Livingston and Boykin (1962). Harris and Browman (pers. comm.) emphasized that sediment studies should include determination of percentage saturation as well as the absolute binding capacity for phosphorus.

In naturally eutrophic lakes, Hutchinson (1973) pointed out that no significant change in the sediment characteristics would be expected with depth. After a short oligotrophic phase, many lakes in temperate, glaciated regions became eutrophic and existed in a state of trophic equilibrium for a long time. In Linsley Pond, USA this steady state condition existed for at least 7,000 years and is represented by a sediment layer 10 m thick.

Even if dredging cannot directly effect a reduction in nutrient loading by removing nutrient-rich sediments to expose a less fertile layer, the interesting possibility of a reduction in nutrient loading via physical deepening exists. If a nonstratified lake can be deepened enough to permit the formation of a stable thermocline, recycling of sediment nutrients to the photic zone may substantially decrease. Lee (1970a) suggested that the loss of the thermocline due to sediment infilling results in a rapid acceleration in eutrophication. The process may be reversible. McCarter et al. (1952) demonstrated that very little phosphorus moves from the hypolimnion, and presumably the deep-lake sediments as well, into the trophogenic zone during thermal stratification. Only a very small hypolimnion may be effective; Rohlich (1963) found that nutrient-bearing materials tend to move into the deepest parts of a lake. Unless meromixis is established, however, at least a portion of the nutrients trapped in the hypolimnion will become available during periods of complete mixing.

Deleterious side effects of dredging may outweigh any benefits associated with the reduction of nutrient releases or nutrient recycling. Dredging may temporarily increase the rate of nutrient release from the bottom sediments by agitation and suspension. During the deepening of a small bay at Lake Herman, South Dakota, USA (Brashier, pers. comm.) orthophosphate concentrations in the lake water doubled. Although dredging could not be directly implicated, the increase was coincident with the dredging operation. In addition, the return waters from dredge spoils are typically high in nutrient concentrations. Chemical treatment for nutrient removal in return waters was practiced at Lake Trummen, Sweden (Björk et al. 1972). Stumm and Leckie (1970) also pointed out that dredging may be detrimental. For example, where fine-grained sediments with a great sorptive capacity are removed and coarser grained sediments are exposed over a large portion of the lake bottom, the buffering capacity of a lake to external changes in nutrient loadings may be lowered.

Nutrient Inactivation/Precipitation

Nutrient inactivation or precipitation within a lake is viewed as a method of hastening recovery of a lake from a eutrophic condition. The intent of an in-lake treatment might be to: (1) change the form of a nutrient to make it unavailable to plants, (2) remove the nutrient from the photic zone, or (3) prevent release or recycling of potentially available nutrients within the lake. There are several possibilities for broad-spectrum or specific nutrient removal via in-lake treatment of waters – once the kind, form, and concentration of nutrients to be controlled have been identified.

The efficacy of using an inactivation approach is dependent upon many factors, including the nature of nutrient sources, hydraulic and nutrient residence times and available removal methods and their economic feasibility. Other important considerations are the immediate and long-term effects on nutrient levels and the nonintentional side effects of nutrient depletion and addition of chemicals on water use, biota and sediments.

Currently available technology and an assessment of controllable nutrients suggest that limiting phosphorus availability is a feasible approach to stemming eutrophication. Metal ion additions for phosphorus removal from wastewaters has become a standard practice, using iron, aluminum and calcium compounds. Recent reviews of the mechanism of phosphorus removal by metal ions (Jenkins et al. 1971; Recht and Ghassemi 1970) and laboratory and pilot-scale work with aluminum, iron, calcium, zirconium and lanthanum (Gahler 1969) indicated that good removals of phosphorus from lake

Nutrient inactivation/precipitation at Pickerel Lake, Wisconsin, USA. Liquid alum was applied at the surface and mid-depth by manifold injection. Photo furnished by Peterson (pers. comm.).

water can be achieved by a combination of sorption, precipitation, and physical entrapment of phosphorus forms.* Removal of suspended solids by precipitants will further reduce nutrients–also, turbidity and color–in the water.

The formation of hydroxide precipitates by ions such as Al (III) or Fe (III) may, however, create a pH problem in relatively unbuffered waters. When using Al (III) as the control agent, this potential difficulty can be circumvented by applying a proper ratio of Al added as alum to that added as aluminate. This technique has been used at Snake and Long Lakes, Wisconsin, USA (Peterson et al. in prep.). Treatment with other metals may require addition of a buffering agent to control pH changes.

Use of ionic aluminum treatment for phosphorus inactivation are shown in Table 6. Treatments of large (>20 ha) lakes have been few but activities have increased in recent years. More detailed information on specific projects is outlined in Part Two of this report.

Other materials being used or considered as coagulants or sorption agents include ion exchange resins, zeolites, polyelectrolytes, aerobic lake mud, flyash, powdered cement and clay. Ohle has contemplated the use of native clays for removal of phosphorus (Malueg, pers. comm.). Fitzgerald (1970) has suggested the use of resuspended lake sediments under aerobic conditions for phosphorus removal. The results should be similar to those using clays or other preformed sorbents, with the advantage of not adding solid materials to the lake (Tenny et al. in prep.). This assumes, however, that the estimated equilibrium phosphate concentration for the sediments (Ryden et al. 1972) is well below the concentration measured in the water (Harris and Browman, pers. comm.). Work with flyash and other materials for lake treatment has also shown promising results (Tenny and Echelberger 1970; Tenny et al., in prep.) and the use of flyash is scheduled for a full-scale trial at Stone Lake, Michigan, USA in 1974 (Tenny, pers. comm.). Goldman (pers. comm.) has, in addition, reported that commercial powdered cement can significantly reduce phosphorus levels under certain conditions.

The distribution and mixing of treatment materials over and through a lake have been accomplished using dry chemical broadcasting and manifold injection. However, because of lake morphology, climatic conditions, thermal structure of lakes and seasonal changes in specific nutrient forms, other methods may need to be developed. Application on ice surfaces, under ice cover, in conjunction with pumped or convective reaeration systems, surface spraying of liquids, etc., are possible techniques which should be tested and demonstrated.

The effect of any nutrient control application on the sediment-water interface is of vital concern. If the treatment results in a covering of the sediment that both retards further nutrient exchange and retains the nutrients that were orginially removed, the chances of success are greatly increased. Laboratory studies by Browman and Harris (1973) on the use of aluminum as a phosphorus control agent, using intact lake cores, have shown:

(1) good removal of inorganic P in the water-sediment systems,

(2) no removal of a major fraction of the indigenous dissolved organic P (<0.45 µg) from the water,

(3) suppression of P release from the aluminum floc and sediments after treatment.

The information available on nutrient inactivation projects suggests that, while experimental trials are being made on lakes and generally encouraging results have been observed, more studies of phosphorus availability to plants and methods

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*The U. S. Patent Office has awarded patent number 3,561,945 to R. W. Kilburn (1971) and the Aqua Kleen Company of Florida for a lake treatment (phosphorus-removal) system using aluminum. Companies in the Midwest, USA have products and processes which are claimed to renovate eutrophic lakes through nutrient inactivation (Buhler, pers. comm.; Laing, pers. comm.).

TABLE 6. Some Lake and Pond Treatments for Nutrient Inactivation

Lake Name	Area (ha)	Maximum Depth (m)	Treatment Applied	Dosage	Date	Summary	References
Långsjön, Sweden	35	3.5	granular aluminum sulfate	50 g/m^3 1,000 kg/ha each treatment	April 1968 May 1970	Nuisance algal conditions and D.O. depletion related to domestic wastes and stormwater nutrient input. Phosphorus reductions, improved D.O. conditions, no change in plankton volumes. Long-term effectiveness limited by continued nutrient input.	Jernelöv, pers. comm. Cronholm, pers. comm. Jernelöv, 1970. Blomsquist et al. 1971.
Grangebergs-viken (part of Södra Hörken) Sweden	15	22	granular aluminum sulfate	70 tons 4,650 kg/ha	Spring 1971	Nuisance *Cladophora* growth. High nutrients from domestic and industrial wastes. Reduction in phosphorus and alkalinity concentrations and effective reduction in *Cladophora* for 2 years since treatment.	Jernelöv, pers. comm.
Fish Rearing Pond, Minnesota, USA	0.4	2.1	granular aluminum sulfate $\bullet$ $14H_2O$ applied to part of divided pond	1,300 kg/ha	May 1971	Fertilized pond. Phosphorus reduction of 90% from 0.5 mg P/l. Blooms of *Anabaena* in treated volume. Growth of *Chara*, pondweeds and walleye fingerlings increased in treated side of pond. No conclusion on effects of invertebrate production.	Bandow 1972. Bandow, pers. comm.
Cline's Pond, Oregon, USA	0.4	2.4–3.0	sodium aluminate neutralized with HCl	10 mg Al/l	April 1971	Eutrophic farm pond. Reduced phosphorus, total nitrogen, suspended solids, and chlorophyll concentrations. No adverse effects noted. Algal production increased the next spring.	Gahler, pers. comm. Gahler et al. in prep. Sanville, pers. comm.
Powderhorn, Minnesota, USA	3.2	7	granular aluminum sulfate	785 kg/ha 1,120 kg/ha	Aug. 1972 Oct. 1972	Algal nuisances. No apparent success, even though floc formation was apparent.	Lundquist, pers. comm.
Horseshoe, Wisconsin, USA	8.9	16.7	granular aluminum sulfate $\bullet 14H_2O$	1,140 kg/ha (injection of slurry near surface)	May 1970	Nuisance aquatic plants and D.O. depletion. Phosphorus removal, enhanced winter D.O., reduced hypolimnetic phosphorus.	Peterson et al. 1973.
Long, Wisconsin, USA	27.5	7.3	liquid alum and liquid sodium aluminate. Dual manifold injection	2,115 gal. aluminate (8,000 l) 3,405 gal. liquid alum (13,000 l); 85 kg Al/ha; 14 mg Al/l in 0.6 m of surface water	May 1972	Demonstrated effects of chemical additions on pH and alkalinity and effectiveness of alum plus aluminate additions for pH and alkalinity control during treatment.	Smith, pers. comm.
Snake, Wisconsin, USA	5.0	5.5	liquid alum (4% Al) and liquid sodium aluminate (13% Al)	930 gal. aluminate (3,530 l) 1940 gal. liq. alum (7,350 l); 12 mg Al/l in 80% of lake volume	May 1972	High nutrient concentrations. Reduction of mean total P concentration of 0.2–0.5 to 0.02–0.07 mg/l in year following treatment.	Smith, undated.
Pickerel, Wisconsin, USA	20	4.5	liquid alum (4% Al)	7.3 mg Al/l in whole lake volume; 163 kg Al/ha	April 1973	Nuisance algal blooms.	Knauer, pers. comm.
Dordrecht Reservoirs, Netherlands			$FeCl_3$	2 mg Fe/l	1962	Eutrophic water supply reservoirs. Reduction in P concentrations increased with settling time. Changes in plankton noted.	Peelen 1969.

for its removal and inactivation are necessary. The distribution of treatment materials and seasonal timing of treatments for maximum benefit are additional topics that need more contemplation and trial.

Dilution/Flushing

Dilution/flushing has primarily been attempted to alleviate excessive algal growths and associated problems by reducing nutrient levels within a lake. This is accomplished by the replacement of nutrient-rich with nutrient-poor waters and the washout of phytoplankton (and the nutrients contained therein). Lake restoration projects have attempted nutrient dilution by two procedures: (1) pumping water out of the lake, thus permitting the increased inflow of nutrient-poor ground water, and (2) routing additional quantities of nutrient-poor surface waters into the lake.

The first procedure has been used in only one instance—Snake Lake, Wisconsin, USA (Born et al. 1973a). Approximately 3-2/3 volumes of water were pumped from the lake to a land disposal site. As a result, nuisance blooms of *Lemna* (duckweed) were eliminated and the nutrient levels were greatly reduced initially. However, phosphorus concentrations were still relatively high and within one year nitrogen had increased to pre-pumping levels. Although leaching from the nutrient-rich sediments limited the effectiveness of this particular experience, the project demonstrated the technical feasibility of the procedure for restoration of small lakes.

The second procedure has been tried in several places. The source of nutrient-poor water has usually been municipal supplies or a nearby watercourse, with conduction to the lake by a diversion pipe or canal. Two of the most successful experiments were at Green Lake, Washington, USA (Oglesby, pers. comm.; Oglesby 1969) and Buffalo Pound Lake, Canada (Hammer 1972). With flushing rates of 3.5 times per year or less the in-lake nutrient levels decreased significantly. In Green Lake, after five years of flushing plus some initial dredging, the blue-green algal standing crop was suppressed and there was a shift in dominance with the elimination of *Aphanizomenon*. Subnuisance levels of blue-green algae were attained after four years in Buffalo Pound Lake; this change was accompanied by a major increase in macrophytes. These experiences affirm that algal control can be achieved by this procedure.

There are, however, many important factors that need to be evaluated prior to implementing any restoration attempt using the dilution/flushing technique.

1. Welch et al. (1972) established that the maximum biomass of problem algal species can be reduced in direct proportion to the amount of dilution water added, providing dilution is lowering the concentration of the limiting nutrient.

Aerial view of the flushing project at Snake Lake, Wisconsin, USA. (a) Pump location. (b) 1969 Disposal field. (c) 1970 Disposal field addition. From Born et al. (1973).

Therefore, the dilution water must either contain lower concentrations (below levels necessary for nuisance growths) of the in-lake limiting nutrient or lack some other constituent that will control algal biomass by becoming the new in-lake limiting nutrient.*

2. Bottom deposits may play an important role in determining nutrient levels within a lake and leaching can negate the potential effects of the influx of nutrient-poor water. This is an important consideration for lakes with extensive shallow water areas and in situations where dilution/flushing is not continuous. Due to leaching the Snake Lake project had only partial success; laboratory studies suggested that continued pumping would have eventually depleted the nutrient content of the sediments (Born et al. 1973a).

3. Lake morphology and hydrodynamics need to be investigated. A dilution/flushing study at Chain Lake, Canada was labeled a failure at least partly due to poor placement of the inflow (Northcote, pers. comm.). Lomax and Orsborn (1971) have studied this problem in laboratory experiments, but much more research is needed.

Although economic considerations and logistics may severely limit the number of applications, the technique can and has been used effectively. Certain in-lake phenomena have been identified as important and thorough pre-treatment investigations should increase the degree of success in future dilution/flushing programs.

Biotic Harvesting

Although biotic harvesting is generally thought of as a maintenance operation (i.e. population control), nutrients are also removed from the lake. The technique has, therefore, been advocated as a practical means of accelerating the nutrient outflow from lake systems. Candidate organisms include both plants and fish.

Algae. Harvesting a standing crop of algae to remove nutrients from a lake is not a new concept, and several methods are now available to remove algae from sewage stabilization ponds (Golueke and Oswald 1965; Kothandaraman and Evans 1972). However, serious technical difficulties have thus far precluded practical in-lake applications.

At this time only filtration appears to have potential. The present utility of microstrainers can be illustrated using the following assumptions:

1. Occurrence of a severe bloom of *Oscillatoria* (10^8 cells/l) near the surface. The algal density will not be uniform and will be strongly influenced by wind action; however, because of the physiological properties inherent to Cyanophyta, the obnoxious species will be concentrated near the surface. This density represents a dry weight of 270 kg *Oscillatoria*/ha for the upper 1 m only (Nalewajko 1966).

2. Algal phosphorus content of 0.5 to 1.0% on a dry weight basis (Gerloff and Skoog 1954; Birge and Juday 1922; Phinney and Peek 1961). The actual content will be dependent upon environmental conditions, species involved, and algal physiology (e.g. luxury consumption).

3. Microstrainer efficiency in removal of blue-green algae near 50% (Klassen et al. 1970; Lond 1969).

Under these conditions 0.68 to 1.35 kg P/ha could be removed from the lake. On a square meter basis, this equals 0.068 to 0.135 g/m^2, which approaches Vollenweider's (1968) dangerous loading rate for lakes with a mean depth of 5 m (0.13 g/m^2, Table 1).

Consideration of the time element, however, emphasizes the shortcomings of implementation. Lond's (1969) microstrainer had a maximum capacity of 540 m^3/hr (aperture size of 40μ and a mesh area of 5 m^2), while the one used by Klassen et al. (1970) could filter 583 m^3/hr. Therefore, using a capacity of 550 m^3/hr., 0.55 hectares could be harvested to a depth of 1 m in a 10-hour day. The fact that it would require 200 days to treat a 100 ha lake makes the usefulness of this technique questionable for nutrient removal, except perhaps in phosphorus-deficient environments and/or in very small lakes. Algal harvesting has been demonstrated experimentally in small bays for cosmetic purposes (p. 20).

Although the values used in these calculations will vary depending upon the individual situation, the technique is presently handicapped by equipment limitations. Some important questions remain unanswered—such as, how much phosphorus contained in the zooplankton and other suspended matter are also removed when the algae is harvested? In general, the present status of this technique severely limits its practicality.

Macrophytes. To satisfy their biological needs, aquatic plants must remove nutrients from their environment. Schults and Malueg (1973) have demonstrated, at least for phosphorus, that rooted aquatics will remove nutrients from both the sediment and water media. These plants not only remove the amount of nutrients they require but they will remove nutrients, if available, in excess of their needs (i.e. luxury consumption, Gerloff 1969). Chapman et al. (1968) have also described the ability of aquatic plants to concentrate elements from their environment.

Although some researchers (e.g. Lee 1970a) have expressed serious doubts about the ability of harvesting to make significant inroads on the nutrient balance of a lake, in some situations where nutrient input is low or where there is a high biomass of macrophytes in relation to the total volume of water (for instance, in shallow ponds), harvesting may remove a significantly large portion of nutrients. Intensive management of coontail *(Ceratophyllum demersum)* might remove as much as 1,100 kg/ha of nitrogen and 200 kg/ha of phosphorus; this was a result of harvesting three crops during the growing season from highly eutrophic ponds in Michigan, USA (McNabb and Tierney 1972). At that rate of harvest 1 ha of managed coontail could remove the nitrogen input from 50 ha, or the phosphorus input from 1,000 ha, of fertilized citrus farm (see Table 5). Also, with reference to Vollenweider's criteria (Table 1), 1 ha of coontail could be harvested to remove inputs 50 and 160 times greater for nitrogen and phosphorus, respectively, than loading levels considered dangerous for shallow waters (mean depth less than 5 m). Nichols (1974) indicated that values up to one-third those found by McNabb and Tierney might be removed by a single harvest of milfoil (*Myriophyllum spicatum* L.) under naturally eutrophic conditions.

Although most harvesting projects are undertaken to cosmetically alleviate the aquatic weed problem, with nutrient removal being a wishful side benefit, there are some notable exceptions. These include the Detroit Lakes project in Minnesota, USA (Peterson, pers. comm.) and the projects for tertiary treatment of sewage plant effluent undertaken at Oshkosh, Wisconsin, USA (Sloey, pers. comm.) and by McNabb and Tierney (1972) in Michigan, USA. These last two efforts follow pioneering studies in West Germany where bulrushes (*Scirpus* spp.) have been used for pond reclamation and sewage treatment (Seidel 1966; Kiefer 1968).

The methodology and effectiveness of harvesting as a control for macrophyte growth along with its resultant costs are discussed in a subsequent section (p. 20). The utility of harvesting projects for nutrient removal is still inconclusive. Projects are few in number and in mostly ongoing stages so that there is no substantive record of successes, failures, or operationality of the method.

Fish. Although Thomas (1965) promoted fish harvesting as a viable nutrient removal technique, it has been implemented in very few lake restoration attempts and always in conjunction with other renewal methods. Nevertheless, any management scheme involving the removal of fish for population control (p. 20) also effectively withdraws nutrients from the lake whether or not it is a stated objective. Therefore, it is worthwhile to examine the possible impact that a fish removal program might have on the nutrient content of a lake.

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*The control of algal biomass can also be achieved in some situations purely by physical washout; this is discussed on page 23.

Knowledge of the nutrient composition of fish flesh as well as the weight of fish removed is necessary for such computations. Although the values presented by Beard (1926)–2.5% nitrogen and 0.2% phosphorus on a wet weight basis–have normally been used, Burgess (1966) raised some doubt concerning their general applicability. Table 7 indicates significant differences between species and also points up a minimum phosphorus content of 0.5%. Also, the nutrient content probably varies between lakes, seasons of the year and size ranges per species; most likely the nutrient content increases with the fertility of the lake and ideally would be highest during the period of optimal harvest efficiency. Duerr (pers. comm.) is now attempting to answer some of these questions in North Dakota, USA waters.

TABLE 7. Nutrient Content of Eight Fish Species*

Species	Nitrogen (Percent)	Phosphorus (Percent)
Pomoxis nigromaculatus (Black crappie)	1.3	0.7
Lepomis macrochirus (Bluegill)	1.0	0.8
Lepomis microlophus (Redear)	1.0	0.6
Chaenobryttus gulosus (Warmouth)	1.4	0.5
Dorosoma cepedianum (Gizzard shad)	3.3	0.6
Notemigonus crysoleucas (Golden shiner)	0.6	0.5
Ictalurus nebulosus (Brown bullhead)	1.4	0.5
Lepisosteus osseus (Longnose gar)	2.6	1.6
Combined Average	1.6	0.7

*Modified from Burgess, 1966; percentages were calculated on a wet weight basis.

The standing crop of fish in a body of water depends on many factors (e.g. water fertility, species composition, etc.). Some of the maximum values presented by Bennett (1962) are: (1) 1,230 kg/ha in an Illinois, USA pond, (2) up to 1,390 kg/ha in Iowa, USA waters, (3) up to 1,100 kg/ha in Kentucky, USA ponds, and (4) up to 1,100 kg/ha of a single type of fish *(Ictiobus)* in some North American waters. Therefore, in some lakes with high standing crops (1,180 kg/ha) and ideal conditions for nearly 100% removal, the nutrient content might be reduced quickly by about 3.0 g/m^2 for nitrogen and 0.24 g/m^2 for phosphorus (0.84 g/m^2 using Burgess' average).

Approximately one-third of these nutrient amounts might be removed annually. The sustainable yield of fish was estimated to be 410 kg/ha and 350-420 kg/ha for Lake Waubesa, Wisconsin, USA (Corey et al. 1967; Helm 1951) and Lake Poinsett, South Dakota, USA (Fox 1968), respectively. The actual amount removable (complete harvest or sustained yield) will depend on standing crop, population dynamics and nutrient content of the fish in each individual lake. These calculations, however, suggest that the quantity of nutrients could be sizable in certain situations and their removal might have a significant impact.

Selective Discharge

Selective discharge has been employed to improve the dissolved oxygen conditions near the bottom and/or to increase the nutrient output from a lake. The implementation of this technique permits the release of anaerobic, nutrient-rich waters from the thermocline or hypolimnion of the lake. The technique can be readily employed in waters with outlet controls, but plastic or wooden pipes have commonly been installed from the normal outflow point to some depth in the lake, most often to the maximum depth. In some reservoirs the pipe extends down the face of the dam into the downstream channel and operates as a siphon. The surface water discharge is often completely blocked off, but in some cases it continues to operate at a reduced intensity. Selective discharge has been evaluated in several restoration attempts; in addition, valuable supplemental information is available from related studies on reservoirs that are operated for the maintenance of high water quality in the downstream channel.

Although dissolved oxygen (D.O.) concentrations have not been maintained at satisfactory levels near the bottom in all lake restoration projects using this technique, the removal of low D.O. or anaerobic water has been beneficial. Some illustrative projects are:

(1) Fanshawe Lake, Canada.

During the summer 15% by volume of the lake became anaerobic before bottom water discharge but only 1% afterwards (Johnson and Berst, 1965).

(2) Twin Valley Lake, Wisconsin, USA

Severe D.O. depletion continued to occur in summer but the duration was shortened. Moreover, winter D.O. levels were increased near the bottom (Wirth et al. 1970).

(3) Kortowo Lake, Poland.

In this case the discharge tube was located at 13 m in a 17 m deep lake. Before installation D.O. depletion occurred at 8 m; after installation, D.O. was always present at 13 m (Olszewski 1961).

Following a statistical examination of conditions in 57 reservoirs, Stroud (1969) also reported that the proportion of water below the thermocline containing D.O. levels of at least 2, 3, or 4 mg/l was directly related to the depth of discharge. The rate of water replacement is important, however. Mainstream reservoirs (short retention time) usually have higher bottom D.O. levels than storage reservoirs (Churchill and Nicholas 1966).

A greater improvement in bottom D.O. conditions during the summer would be expected except for the concurrent effect that selective discharge has on temperature. The release of cooler water from the bottom results in elevated temperatures at that location. Although the degree of change is dependent on the outflow and lake volumes, warming typically results from a selective discharge project (e.g. Wirth et al. 1970; Johnson and Berst 1965; Olszewski 1961). As a consequence the rate of chemical reaction may be greatly accelerated in the bottom waters, thus placing an increased demand on the oxygen resources. Although selective discharge promotes higher D.O. concentrations in the bottom waters, this may be partly negated by the heightened rate of utilization.

During conditions of D.O. depletion, selective discharge also increased the nutrient outflow from a lake. Intense chemical stratification was eliminated in several projects (e.g. Duever, pers. comm. Wirth et al. 1970), and increased quantities of nutrients have been measured in the discharge waters (Pechlaner 1971; Wirth et al. 1970). During the 1-¾ years of study at Twin Valley Lake, USA 25 and 22% more N and P, respectively, would have been released by a bottom water discharge versus a surface discharge. This was primarily due to the discharge of nutrient-rich water during the summer months (Wirth et al. 1970).

The release of anaerobic, nutrient-rich waters has caused some problems in the downstream channels. Although reaeration can be provided by sufficient turbulence in the discharge, an oxygen sag may develop downstream. At Twin Valley Lake a high oxygen demand in the discharge waters coupled with increased macrophyte growths in the watercourse resulted in low D.O. levels at night (Wirth et al. 1970). Also, noxious gases (e.g. hydrogen sulfide) may be released from the discharge waters (e.g. Hämäläinen 1969); and below Schweitzer Reservoir in Michigan, USA the floc caused by iron oxidation has smothered invertebrates and covered fish spawning areas (Wright, pers. comm.). The release of these gases and the downstream effects have been major criticisms of the selective discharge technique.

Due to the short-term nature of most lake restoration studies, there is a serious lack of reliable information concerning the biological consequences of selective discharge. Although some changes in the biotic community have been noted during selective discharge, cause-and-effect relationships have not been clearly established. Perhaps the only exception was at Kortowo Lake, Poland–plankton populations occurred at increased depths following improvement in the D.O. conditions (Olszewski 1961). Jenkins (1970a) found a positive correlation between the outlet depth and the reservoir sport fish and total fish standing crops through a statistical analysis of the fish populations in 140 reservoirs; however, a fish population response has not been identified to date in any lake restoration attempt using selective discharge.

Other than the lack of biotic response information, the primary need seems to be guidelines regarding how to maximize D.O. improvement and/or nutrient output. In fact there may be some situations where both cannot be maximized; the greatest nutrient release would be expected under anaerobic conditions. At present, selective discharge is known to promote improved D.O. conditions and increase nutrient outflows, but there still are important informational gaps associated with efficiency and overall effectiveness.

Sediment Exposure and Desiccation

Sediment exposure and desiccation via lake drawdown has been suggested as a means of stabilizing bottom sediments and retarding nutrient release. Drawdowns have been undertaken on impoundments for a variety of reasons (p. 20) and the feasibility of dewatering natural lakes with high capacity irrigation pumps has also been demonstrated recently (Smith et al. 1972; Born et al. 1973a). However, the effect of drying on sediment chemistry and subsequent nutrient release is frequently overlooked.

Usually only the upper few centimeters of lake sediments are involved in interchange with the overlying lake water (Lee 1970c), and any changes in this layer during drawdown may have a significant effect on water quality after reflooding. By reducing the sediment oxygen demand and increasing the oxidation state of the surface layer, drawdown may retard the subsequent movement of phosphorus from the sediments. Mortimer (1941) found that a thin (1 cm) oxidized layer at the sediment-water interface retarded the release of phosphate to the overlying water and Fitzgerald (1970) also demonstrated the phosphorus binding capacity of aerobic lake sediments.

Sediment exposure can also curb sediment nutrient release by physically stabilizing the upper flocculent zone of the sediments, which plays an important role in the exchange reactions and mixing of the sediments with the overlying water (Lee 1970c). During lake drawdown these fluid sediments either flow to the deeper parts of the lake or consolidate (Smith et al. 1972), thus physically reducing the exchange potential.

On the other hand, agricultural studies of organic soils suggest that lake sediment desiccation will accelerate microbial conversion of the organic forms of nutrients to inorganic forms (Davis and Lucas 1959). These may then be available for plant growth upon reflooding. Drawdown and dry fallowing with subsequent reflooding are widely used to increase the fertility of fish culture ponds (Neess 1946; Sniesko 1941). Armstrong and Lee (1972) found that drying sediment samples from several different lakes had variable effects on inorganic and NaCl-extractable phosphorus levels, but some of the samples showed tremendous increases in the NaCl-extractable fraction after freezing or rewetting. Gahler (1969) also found increases in the soluble phosphorus fraction of sediment samples after freezing.

Keeney and Bryans (1972) reported similar results for nitrogen in dried or frozen sediment samples. They concluded that drying resulted in a physical breakdown of organic gels, thereby increasing the surface area of organic material for microbial attachment and leading to a more rapid mineralization of organic nitrogen upon rewetting. Rapid nitrification of ammonia to nitrate was observed in some samples, but denitrification after rewetting restored the initially low levels. Large increases in ammonia nitrogen during several cycles of freeze-thaw were attributed to a disruption of cellular organic materials during freezing, coupled with a rapid repopulation of microorganisms during thawing.

Sediment chemical analyses were performed to assess effects of drawdown on Lake Tohopekaliga, Florida, USA, but laboratory error tended to obscure the expected reductions in sediment concentrations of ammonia, organic nitrogen and volatile solids. A gas evolution test on the sediments did show, however, that the exposed organic sediments released several times more carbon dioxide than exposed sandy sediments or submerged organic sediments, indicating a high degree of microbial activity (Wegener and Holcomb 1972).

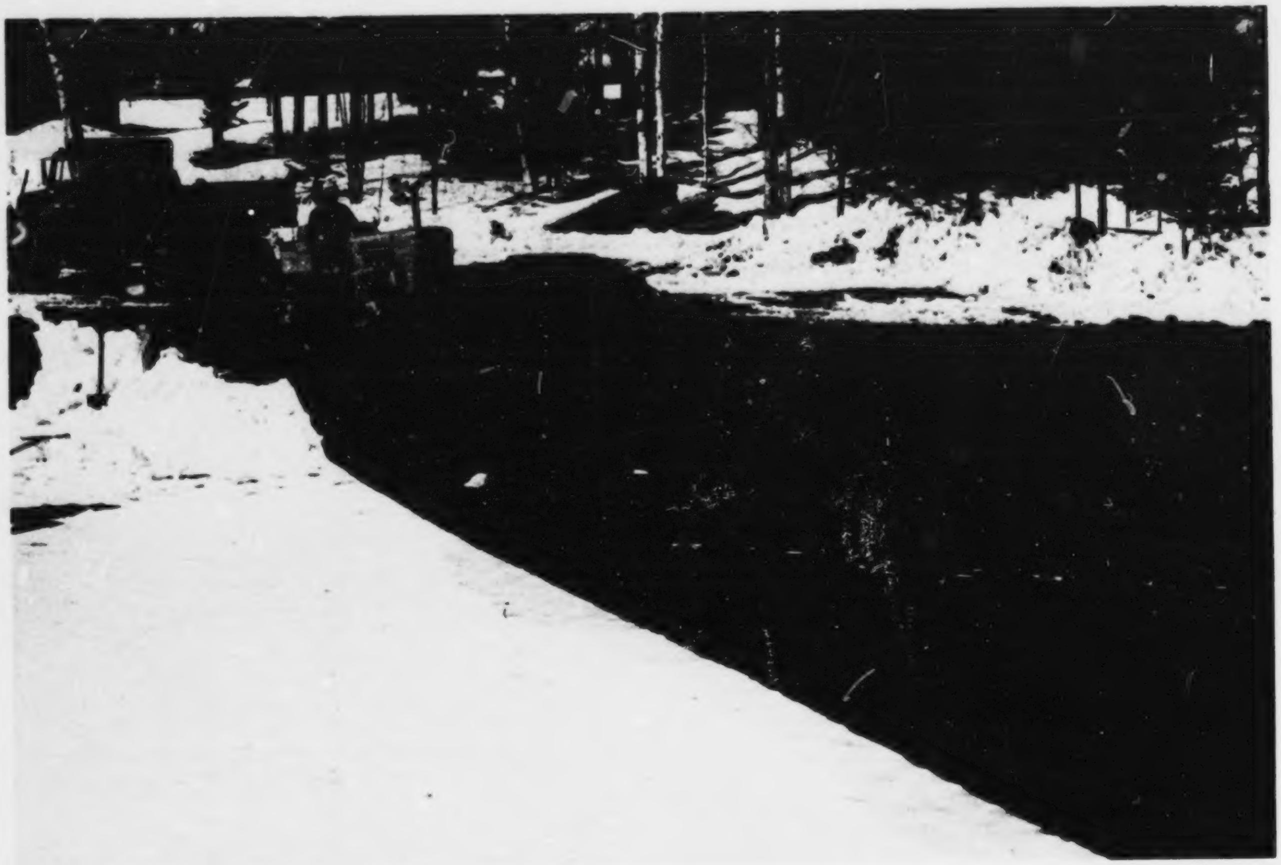
The meaning of these studies as regards nutrient control via sediment exposure and desiccation is indefinite. Laboratory experiments and agricultural and fish farm observations suggest that drying or freezing exposed lake sediments could result in the mobilization of phosphorus and nitrogen upon reflooding, but the combined effects of sediment stabilization, a decreased oxygen demand and a greater phosphorus binding capacity may outweigh any increases in soluble nutrient levels. Syers et al. (1973) pointed out the importance of the iron (Fe) content of sediments and the role of the Fe2+ $\rightleftharpoons$ Fe3+ balance in controlling the dissolved phosphorus concentration in sediment-water systems. However, much investigation is still needed for a clear understanding of the efficacy of using drawdown and desiccation for nutrient control.

Lake Bottom Sealing

Lake sediments commonly contain significant amounts of exchangeable nutrients (Tenney et al. in prep.). Although the physical removal of these sediments is often recommended to reduce a lake's nutrient content, bottom coverings may provide control at less cost. Several covering materials show promise of suppressing the transport of nutrients from the sediments into the overlying waters either by physically retarding exchange or by increasing the capacity of surface sediments to hold nutrients. In addition, some coverings can inhibit macrophyte growth by elimination of suitable substrates, provide erosion control by bottom stabilization and minimize water loss via infiltration.

Plastic sheeting and rubber liners have great potential as sediment coverings. In one instance, perforated black polyethylene was installed in the littoral zone and covered with sand and gravel (Born et al. 1973b). The sheeting permitted macrophyte control and beach development. Perforations in the sheeting allowed the vertical transport of gases while serving to retard nutrient release from the bottom (Hynes and Greib 1967, 1970). Kumar and Jedlicka (1973) reported on materials and costs of construction of lined ponds for the chemical process industries.

Mineral soil coverings have also been used. Prior to inundation, reservoir soils were covered to retard release of nutrients, metals and colored materials, thus protecting water quality (Sylvester and Seabloom 1965). In laboratory studies, several centimeters of sand were effective in suppressing



The ice on Windfall Lake, Wisconsin, USA was covered by plastic sheeting overlain with sand. During the spring thaw, the plastic and sand settled onto the lake bottom. Photo furnished by Nichols (pers. comm.).

nutrient release from the reservoir soils. Although controlled experimentation is not conducted, Müller (pers. comm.) also reported that dredge spoils, mostly sand, are commonly used in West Germany to cover lake sediments.

Other materials that appear to have merit as bottom sealants include flyash, clays, hydrous metal oxides and certain gels. These materials serve a dual function. Phosphorus compounds can be removed from the overlying waters during treatment (p. 10) and the formation of a bottom covering serves to retard transport of nutrients from the sediments into the water.

The use of flyash is now under study (Tenney and Echelberger 1970). Pilot tests involving applications in two 1 acre (0.4 ha) ponds are preliminary to a planned nutrient inactivation/precipitation treatment of Stone Lake, Michigan, USA in 1974 (Tenney, pers. comm.; Yaksich and Tenney 1972). Concommitant studies include the effectiveness of flyash as a bottom covering, in terms of stability and nutrient suppression. Application costs are estimated at $2,500 USA/ha.

Tenney et al. (in prep.) presented data on the use of clay in suppressing phosphate transfer. The sorptive capacity of clay for phosphorus is, however, relatively low and poor settling characteristics may require additional processing to make treatment feasible (e.g. the use of a coagulant aid).

The use of hydrous metal oxides for lake treatment results in the formation of a flocculent layer at the sediment surface. The layer provides sorptive capacity for phosphate as well as an additional physical layer to retard transfer of nutrients. Wildung and Schmidt (1973) have concluded that the easily leached inorganic P in sediments is in the iron-associated fraction and that resorbed P was associated with aluminum. Increasing the P-sorption capacity of the sediments (e.g. by addition of aluminum compounds) should decrease the amount of dissolved P in the lake water. Laboratory studies using intact cores overlain by lake water have shown that aluminum (III) treatment is very effective in not only reducing phosphorus levels in the water column but also in retarding sediment release of phosphorus under anoxic conditions (Browman and Harris 1973). The redox conditions do not effect phosphorus sorption by aluminum and retardation has been noted for over one year (Harris and Browman, pers. comm.). The flocculent layer is susceptible to scouring and resuspension, however.

Gels have not been used for sediment treatments in lake restoration, but those described by Chung (1973) or those developed as sediment control aids for oceanographic salvage operations are worthy of investigation. The potential value of these gels as bottom sealants justifies future study of their nutrient-uptake properties.

Despite encouraging results regarding nutrient control by sediment covering, important questions remain. How permanent is the treatment? Will the barriers become disrupted and ineffective due to lake mixing or biological activity (Brinkhurst 1972)? What effect do these barriers have on benthic organisms and fish spawning success? Theory and some data are available on side effects (Nichols, pers. comm.; Peterson et al. in prep.), but more work is needed in these areas.

MANAGING THE CONSEQUENCES OF LAKE AGING

In many situations the nutrients, sediments or other undesirable materials are already in the lake and little can be done to directly control them or negate the problem source. The alternative in these cases is to treat the consequences or "symptoms" in order to provide a more usable resource until more permanent solutions can be achieved. Several techniques are available to manipulate the biota and environment within a lake, thereby enhancing its potential use. Some of these produce results as effective and satisfactory (in terms of use requirements) as nutrient limitation schemes and are considerably easier to implement.

The identification of an undesirable situation is, however, imprecise and largely determined by subjective judgments. The judgments depend on a particular situation and will vary from person to person, lake to lake, region to region and user type to user type. Nobody has stated, for instance, how many metric tons per hectare of macrophytes are in a desirable lake (for some specified use or uses) versus an undesirable lake or how the size of a fish from a desirable lake compares with that of an undesirable lake. A shallow, weedy bay may be very desirable to the sport fisherman but highly undesirable for the water skier. Similarly, the common carp is a desirable fish in parts of the world but is generally considered undesirable in North America. Therefore, the determination of objectives and standards for lake resource management is a science dependent on the value judgments and expectations of the people involved.

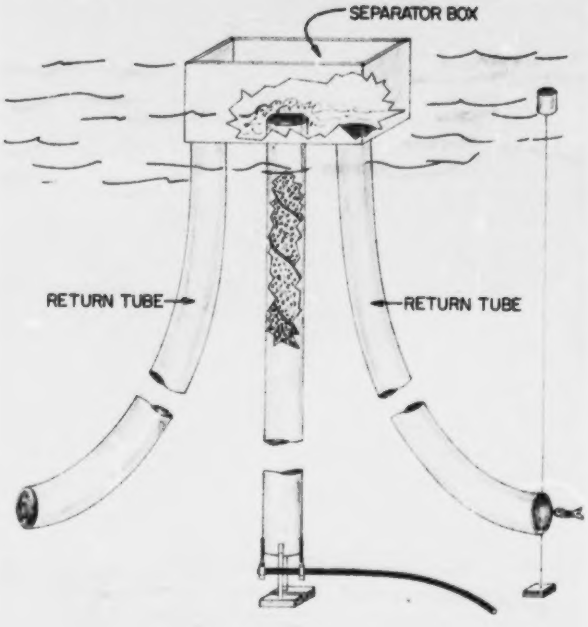
Once problem identification has occurred, a management choice can be made from a variety of physical, chemical and biological control techniques. Particular care must, however, be taken in considering potentially deleterious side effects associated with these management methods. A natural ecosystem is made up of innumerable, complex interactions (biotic and abiotic) that are incompletely understood. Alteration of a system to control an undesirable characteristic can produce unwanted responses in other features. Management objectives should include the maintenance of a relatively natural ecosystem with ecologic diversity (as opposed to a community swimming pool) while upgrading usability.

Aeration and/or Circulation

Circulation and aeration by mechanical means is a common method of increasing the use potential of lakes. The basic objective behind virtually all aeration projects is improved dissolved oxygen conditions for fishery or water quality management purposes but because of differences in technique and the effects of aeration on the thermal regime of a lake, it is convenient to recognize two separate categories—total aeration and hypolimnetic aeration.

The terms "total aeration" and destratification" are frequently used interchangeably and refer to the technique of increasing the dissolved oxygen content of the bottom waters of lakes by eliminating thermal stratification and homogenizing the entire water volume. Destratification is usually accomplished by lifting cold hypolimnetic water to the lake surface, where it mixes with the warmer epilimnetic water and absorbs oxygen before sinking back to a new equilibrium depth. The entire lake can be circulated and aerated from a single site and it will eventually become almost isothermal.

The energy required to lift the denser bottom water can be supplied by either mechanical water pumps or compressed air released at the lake bottom. With either method, atmospheric oxygen transfer at the lake surface and photosynthetic oxygen production play an important role in the aeration process. King (1970) noted that even with the use of compressed air only 2 to 8% of the injected oxygen is absorbed by the water; Symons et al. (1967b) could not detect any appreciable oxygen uptake from a diffused air destratification system installed in a Kentucky, USA reservoir.



Hypolimnetic aerator used at Mirror Lake, Wisconsin, USA. Diagram furnished by Smith (pers. comm.).

Various types of aeration devices have also been used in an attempt to prevent dissolved oxygen depletion and fish winterkill in lakes during periods of ice cover, but the most popular methods are similar in design to total aerators. Compressed air is released from the lake bottom and the rising bubbles carry the slightly warmer bottom water to the surface to maintain an ice-free area. These aeration attempts have met with varying degrees of success (Greenbank 1945; Patriarche 1961; Seaburg 1966; Wirth 1970); however, most failures are probably due to undersized systems (Toetz et al. 1972).

One disadvantage of total aeration is the change in the lake's seasonal heat content. Thermal gradients are eliminated and the temperature of the entire water mass may approach the normal surface temperature. This is a serious problem during the summer; destratification can completely eliminate potential cold water fish habitat and the cool hypolimnetic water preferred for municipal and industrial water supplies.

In recognition of the shortcomings of total aeration, several types of aeration devices have been designed to improve dissolved oxygen conditions in the hypolimnion of stratified lakes without disrupting thermal stratification. Typically the bottom water is airlifted up a vertical tube; the rising bubbles are vented to the atmosphere and the bubble-free water is returned to the hypolimnion. One notable exception to this design is the hypolimnetic aerator described by Mercier and Perret (1949), in which water was pumped from the hypolimnion to a shore facility where it was sprayed into the air, collected and returned to the hypolimnion. Speece (1971) described several other approaches to hypolimnetic aeration, all of which are in the experimental stage, including U-tube aeration, deep bubble injection and downflow bubble-contact aeration. Because oxygen transfer is limited to the bubble-water interface in most hypolimnetic aerators, oxygenation is slower than with aeration by destratification.

Some of the effects of artificial aeration on physical and chemical parameters are quite predictable, but the response of the biota is frequently inexplicable and has received inadequate attention. Oxygenation of bottom waters leads to a general increase in the oxidation state and a reduction in the concentrations of the reduced forms of iron, manganese, nitrogen, and sulfur (Irwin et al. 1966; Wirth and Dunst 1967; Symons et al. 1970; Haynes 1971). The elimination of these chemical species and their resultant taste and odor problems has been the goal of many aeration projects in water supply reservoirs (Symons et al. 1970). Destratification of water supply reservoirs also has been used to reduce evaporation losses by lowering surface water temperature (Koberg and Ford 1965).

Fast (1971a) and Mercier (1955) reported that aeration increased the rate of oxidation and decomposition of bottom sediments and organic matter in the water column, but circulation and suspension of sediments and decomposing plant cells also increases the oxygen demand (Fast 1971a). Aeration should promote the sorption of phosphorus by the hydrous oxides of iron and manganese (e.g. Lee 1970c; Mortimer 1941; Wildung and Schmidt 1973), but Fast (1971a) found that the increased sediment temperatures associated with destratification accelerated nutrient release. Wirth et al. (in prep.) found that hypolimnetic aeration led to substantial reductions in the concentration of phosphorus in bottom waters.

Artificial aeration and circulation has an important effect on certain segments of a lake's biota, but the observed results are contradictory. Haynes (1971) found that destratification destroyed blue-green algae scums by circulating the cells throughout the water, but had little effect on the total biomass. However, Malueg et al. (1971) noted a decrease in the total standing crop of blue-green algae during aeration. Increased numbers of green algae have been observed during several aeration studies (Robinson et al. 1969; Haynes 1971; Hooper et al. 1952). Ridley (1971) found that blue-green algae increased during partial destratification and suggested that the timing of the onset of destratification with respect to seasonal production was of great importance in determining algal response. MacBeth (1973) suggested that changes in pH and CO_2 concentration were responsible for changes in algal types in several Ontario, Canada destratification projects.

The effects of aeration on zooplankton and zoobenthos are unclear. Lackey (1971) reported that aeration resulted in a change in the dominant species of zooplankton and Linder and Mercier (1954) found an appearance of species more characteristic of oligotrophic conditions. Fast (1971b) found that aeration resulted in an extended vertical distribution of zooplankton and a rapid invasion of the profundal zone by zoobenthos, but Lackey (1971) noted no significant changes in benthic population during destratification.

Destratification can enlarge the habitat of warm water fish, which are normally restricted to the upper oxygenated waters during hypolimnetic oxygen depletion (Hooper et al. 1952; Irwin et al. 1967; Wirth and Dunst 1967; Fast 1971a), but few studies have actually documented beneficial effects. A notable exception is the work of Johnson (1966), who reported greatly increased survival and production rates of coho salmon *(Oncorhynchus kisutch)* fry during artificial destratification. Fast and St. Amant (1971) operated a destratification system at night in a southern California, USA reservoir in an attempt to provide suitable temperature and dissolved oxygen conditions for rainbow trout *(Salmo gairdnerii)*, but temperatures rose above critical levels. In a later study, Fast (1971a) demonstrated the use of hypolimnetic aeration in increasing the living space available to rainbow trout in a Michigan, USA lake but did not investigate any potential long-term response.

In summary, aeration has been shown to have a positive effect on the dissolved oxygen regime of eutrophic lakes and reservoirs. Aerators can be tailored to alleviate certain water quality problems and enlarge the habitat available to either cold or warm water fish species. However, if fish management continues to be a major objective of aeration, more justification of the energy and effort expenditure is necessary. Thus far, few projects have demonstrated a desirable fish population response to the apparently enlarged habitat. In addition, the effect of aeration on other segments of the lake's biota, particularly phytoplankton and zooplankton, requires more thorough investigation.

Lake Deepening

Decreased lake depth resulting from organic and inorganic sedimentation is one of the common consequences of lake aging. At the lowest elevation in a drainage system, lake beds serve as a receptacle for water-transported materials. Even when measured against the human time scale, lake infilling can be a rapid process and is the controlling factor in the life expectancy of most lakes.

Shallow lakes often contain extensive growths of rooted aquatic plants and are more prone to winterkill than deep lakes. Deepening reduces the size of the littoral zone, provides additional water surface suitable for recreational use, decreases the ratio of sediment surface to water volume and can create a sufficient volume of oxygenated water to prevent the onset of anaerobiosis during periods of ice cover. Patriarche and Merna (1970) noted that increasing the depth of water by a small amount (15-30 cm) completely eliminated fish winterkills in a small Michigan, USA lake.

Lake deepening can be achieved by physical removal of lake sediments (dredging) or by sediment consolidation. Artificially raising and maintaining the lake level via damming the outlet or increasing the rate of water inflow are also possible under certain circumstances.

Dredging

There is a substantial body of literature devoted to large-scale dredging operations for navigation improvements, fill emplacement and placer mining (Herbich and Snider 1969; Giroux 1952; Erickson 1962), but considerably less data are available on small-scale lake deepening projects. Pierce (1970) reviewed the techniques for inland lake sediment removal and noted that the hydraulic dredge was the most effective tool used on the majority of lake deepening projects. The recent development of small, highly portable dredges has further increased their popularity but costs are still a major obstacle, ranging from $0.06 to $1.93 USA/$m^3$ of material removed. A unit cost of $0.60 to $0.80 per m^3 is about average (see P Two). The use of other types of excavation equipment (e.g. dragline and Sauerman bucket) can produce cost advantages under special circumstances but are limited in application.

Complete and reliable data on the effectiveness of dredging are lacking, but information from selected lakes investigated by Pierce (1970) in the Upper Midwest, USA indicates that the goal of physical deepening was accomplished successfully in all of the completed projects. Additional projects have been recently initiated in Michigan, USA where new lakes are being created at the expense of wetland areas by the use of a hydraulic dredge modified to handle bog mat (Engineering News-Record 1973).

The success of lake dredging projects is usually expressed only in terms of increased depth. A common criticism leveled at dredging projects is the lack of careful attention to the environmental effects (e.g. Reuter vs. Wis. Dept. Natural Resources 1969). Dredges do create abnormal turbidity during operation and suspension of the sediments can increase the oxygen uptake rate by a factor of ten (Seattle Univ. 1970). Suspension and agitation of the sediments may also promote the release of nutrients (p. 10). Moreover, a major dislocation of zoobenthos has been noted on dredged lake beds (Wilbur and Langford 1972a; Carline, pers. comm.). A long-term study is currently underway in Wisconsin, USA to determine re-invasion rates of disrupted benthic populations. Preliminary results indicate that more than two years will be required for re-establishment of the bottom fauna (Carline, pers. comm.).

Drawdown and Sediment Consolidation

Sediment consolidation has the potential for alleviating many of the economic and environmental obstacles associated with dredging although its effectiveness is highly dependent on lake and sediment characteristics (Smith et al. 1972). The technique involves lake drawdown and sediment dewatering. Artificial lakes with suitable outlet structures can be gravity drained and the feasibility of lowering the level of natural lakes with high capacity pumps has also been demonstrated (Born et al. 1973a; Smith et al. 1972).

The water content of the organic-rich sediments in eutrophic lakes frequently exceeds 90% on a volume basis; complete dewatering could decrease sediment thickness by a corresponding amount. The water content of inorganic sediments is usually considerably lower, but if an appreciable clay-sized fraction is present, consolidation will still occur. Of course, complete removal of pore water and 100% consolidation is not normally possible, but Selbig (1970) noted that even a relatively small amount of consolidation (28 cm) during the drawdown of Beaver Dam Lake, Wisconsin, USA increased the lake depth by 11% and was beneficial to the fishery. At Snake Lake, Wisconsin as much as 1 m of consolidation took place during a 3 m drawdown (Born et al. 1973a) and at Lake Tohopekaliga, Florida, USA consolidation of flocculent organic sediments in the near-shore areas ranged from 55 to 100% during drawdown (Wegener and Holcomb 1972). Drawdown also provides an opportunity for shoreline improvements such as sediment excavation, sand blanketing and rip-rapping by conventional dry land procedures (Born et al. 1973b). The significance of sediment erosion must, however, be evaluated before exposure.

The effect of drawdown on the physical characteristics of the sediments is largely irreversible. Consolidation of flocculent sediments produces a permanent rearrangement of the structure; no appreciable reswelling would be expected after lake refilling. Sediment exposure and desiccation may, however, result in chemical changes within the sediments that may have an undesirable effect on nutrient levels in the lake after reflooding (p. 16). Further quantitative documentation of this technique is warranted.

Other Physical Controls

Some techniques have a long history of use in management while others have been developed only recently. Most of the procedures have received some evaluation but thorough documentation is limited in terms of lake restoration. Physical control techniques considered here are somewhat arbitrarily divided into three groups: (1) harvesting, (2) drawdown, and (3) habitat manipulation.

Harvesting

Algae. The only known in-lake study of algal harvesting as a management practice was conducted in Clear Lake, California, USA using a microstrainer (Sabanas et al. 1970). The removals were made for cosmetic purposes in small bays where *Aphanizomenon* was considered obnoxious and excessive. An oil skimmer was used to collect floating blue-green algae which were then pumped through the microstrainer for removal. This investigation was, however, designed to produce data on mesh sizes and efficiencies of cellular removal; further studies will be necessary prior to full-scale implementation.

Another procedure by which algae can be harvested was used during a dilution/flushing experiment at Snake Lake, Wisconsin, USA where lake water was pumped to a land disposal site. Although a plankton study was not incorporated into this project, algae would have occurred in the pumped water and would have been removed by filtration through the soil. This methodology may be of value and applicable in certain situations.

In addition, there are several other techniques of physically removing algae from the epilimnion although total removal from the lake is not involved. These techniques have mostly been discussed elsewhere in this report (e.g. nutrient inactivation/precipitation projects); however, an additional technique was described by Menday and Buck (1972). Explosive charges were used to deflate the gas vacuoles of blue-green algae in English reservoirs (United Kingdom). Walsby and Buckland (1969) determined that the pressure necessary to burst gas vacuoles of *Anabaena flos-aquae* is approximately 4.5 kg/cm^2. Menday and Buck (1972) found similar pressures would deflate vacuoles of *Microcyctis aeruginosa*. At a pressure of 6.0 kg/cm^2, 80% of a suspension of *M. aeruginosa* settled in 8 minutes under laboratory conditions. Unfortunately, the technique has adverse effects on fish, ruptured swim bladders being a major cause of death. The pressure peaks required (4.5 kg/cm^2) to sink algae can be achieved at a cost of less than $20 USA/ha using lines of charges. Nevertheless, this technique would not be recommended as a regular means of algal control.

Macrophytes. The rationale for weed harvesting varies. Some people view weed harvesting as no more than "mowing the lawn" but they are willing to do it, even though it will be a continuing effort, because it makes their surroundings more pleasant and usable. Others feel that by undertaking a continual harvesting effort, sufficient stress can be placed on the plant so it will die or other more desirable species will take its place. In fact, the truth probably lies somewhere in-between.

Studies by Nichols and Cottam (1972) indicated that harvesting significantly reduced the biomass of plants (primarily *Myriophyllum spicatum* L.) not only during the year of harvesting but also in the subsequent year. Over the three-year course of their study, however, there was no perceptible change in the species composition of the plant community. Nichols (1974) surveyed the identifiable users of harvesting equipment in the states of Michigan, Minnesota, and Wisconsin, USA. Of 32 users, 6 indicated that harvesting has a long-term beneficial effect. In other words, harvesting operations could be scaled down or halted after one or more years of intensive harvesting because the weeds become less of a problem. Most respondents (23) agreed that harvesting had a short-term beneficial effect. That is, if harvesting was done often enough and continued year after year the lake was more usable. Only three felt that conditions were not improved or had even worsened after harvesting efforts.

The harvesting technique is workable and machines have been developed which will successfully harvest kelp in the ocean, lake weeds in freshwater and water hyacinth *(Eichornia crassipes)* in the Louisiana Bayous. The machinery and methods along with some of the successes and failures have been reviewed by Livermore and Wunderlich (1969) and Nichols (1974).* Bruhn and Livermore (1970) described a harvesting system under development that is potentially more efficient and effective than the traditional methods. Its basic components are a high speed cutting unit and a secondary pickup unit. There has also been a variety of machinery developed or proposed for specialized weed problems such as water hyacinth (Wunderlich 1938) and emergent plants (Björk 1972b). In addition, Carranza and Walsh (1972) have suggested the use of oil skimmers for harvesting duckweeds *(Lemna)* and *Spirodella*.

Conventional harvesting machines are relatively slow, capable of harvesting about one-half hectare per year and

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*Laser technology is now being examined as a physical control procedure for macrophytes (Couch 1973).

Weed harvester in operation on Lake Monona, Wisconsin, USA. Photo furnished by Bruhn, Livermore and Koegel (pers. comm.).

cannot work in water depths of less than 30-60 cm. Typical operating costs (wages, fuel and amortization of machinery) range from $50 to $140 USA/ha but may run as high as $450 to $900 per mile (1.6 km) of 10 foot (3 m) wide canals in Florida, USA (Weeds Today 1972). [For a further review of harvesting statistics, see Nichols (1974)].

Two points related to harvesting merit additional discussion. If a program of cutting without plant removal is undertaken, caution is necessary so that problem species are not spread vegetatively. Most aquatic weeds spread very rapidly by vegetative means; cutting without removal merely provides untold numbers of vegetative propagules. A second problem confronting harvesting concerns the utilization of the plants and is the subject of much current research (Koegel et al. 1972; Little 1968; Bagnall et al. 1971). If viable methods are developed for utilizing aquatic weeds, they will become a resource and much more effort will be spent studying methods to optimize plant yield and harvesting techniques.

Fish. Population reduction programs normally have one or both of the following objectives: (1) to increase the growth rate of slow-growing but desirable fish species by removing a part of the population, and (2) to decrease the population of undesirable species in order to favor the expansion of desirable species. A variety of gear has been used–nets, traps, dynamite, and electrical equipment–depending on the characteristics of the fish species and the conditions in the lake. Liberalized fishing regulations have also been adopted in order to increase the rate of removal.

As indicated in Part Two of this report, some success has resulted from mechanical removal programs, but an intensive effort has usually been necessary. The basic problem in fish harvesting is that adult fish are preferentially removed by the gear. Laboratory work such as that conducted with *Lebistes reticulatus* (guppy) by Silliman and Gutsell (1958) emphasizes that very high exploitation rates will usually be required when only adults are removed. In their experiment, exploitation rates of 25 and 50% were compensated for by increased numbers of juveniles. Also, when adults of a desirable species are removed, poor fishing can result (Snow 1962). Mechanical removal will be much more effective if equipment can be developed to efficiently limit the numbers of juveniles.

According to Jenkins (1970b) angling restrictions originated as a trout management technique and were simply extended to warm water environs. Due to overabundance and/or slow growth of certain species in eutrophic waters, studies have been initiated to determine the effects of liberalizing these restrictions. The results have ranged from no effect on the fish population or the sport fishery (Pelton 1948) to a greatly increased harvest and growth rate (Bennett 1945). In the latter instance, however, the harvest decreased after the first year due to a reduction in the adult fish population. Therefore, because adult fish are removed, liberalized fishing produces an effect similar to that of the mechanical removal techniques discussed previously. Liberalization is advantageous in terms of increased angler catch and reduced cost of removal; nevertheless, the method is dependent on heavy fishing pressure and is inadequate for the control of undesirable fish species.

In summary, population reduction programs of both types have definite shortcomings but can be used with some success. Although the effort must be intensive and continuous, there may be many situations where this technique is the most feasible from an ecological and economical standpoint. Future studies should, however, determine the exploitation rate for a particular species and relate it to the effects of removal. Reliable guidelines to suggest the exploitation rate–and therefore the quantity of fish that must be removed, effort required and cost–needed to produce the desired results are presently not available.

Water Level Fluctuation

Macrophytes. Drawdown (lowering of water levels) influences the macrophyte composition and density primarily through desiccation, freezing, mechanical removal and/or sediment compaction. Drawdown is achieved by managing discharge–where outlet structures exist–or by pumping the water out of lakes using high-capacity pumps. Smith et al. (1972) and Born et al. (1973a) discussed the use of high capacity pumps for managing water levels in lakes that do not have manageable outlet structures. Most evaluations have thus far been concerned with overwinter drawdowns and results have generally been satisfactory.

Overwinter drawdown of water gave good control of some submerged aquatics in Murphy Flowage, Wisconsin, USA (Beard 1969, 1973) and Mondeaux Flowage, Wisconsin (Nichols 1974). The long-term effects of annual overwinter drawdown to macrophytes common to the area were determined during a study of the Chippewa Flowage, Wisconsin (Nichols 1972, 1974); certain species were definitely vulnerable to drawdown (Table 8). Overwinter drawdown exposes plants to freezing and desiccation. Frost heaving of large water lily (*Nymphaea* spp. and *Nuphar* spp.) rhizomes also appears to be a mechanical removal technique resulting from overwinter drawdown. In the southeastern United States, Lantz et al. (1964) did similar work with drawdown in Louisiana and Smith et al. (1967) used drawdown for control of Eurasian water milfoil *(Myriophyllum spicatum)* in the Tennessee Valley Authority lakes. In all cases reviewed, overwinter drawdown appeared to be a very effective and cheap method of weed control.

TABLE 8. Preference of Common Macrophyte Species to Water Level Management*

Prefer Fluctuating Water Level

- *Acorus calamus*
- *Glyceria borealis*
- *Leersia oryzoides*
- *Najas flexilis*
- *Polygonum coccineum*
- *Polygonum natans*
- *Potamogeton epihydrous*
- *Potamogeton foliosus*
- *Potamogeton gramineus*
- *Potamogeton richardsonii*
- *Salix interior*
- *Scirpus validus*
- *Sium suave*
- *Typha latifolia*

Prefer Stable Water Level

- *Asclepias incarnata*
- *Brasenia schreberi*
- *Eleocharis acicularis*
- *Nuphar variegatum*
- *Nymphaea tuberosa*
- *Pontederia cordata*
- *Potamogeton amplifolius*
- *Potentilla palustris*
- *Sagittaria heterophylla*
- *Utricularia vulgaris*

No Preference

- *Ceratophyllum demersum*
- *Vallisneria americana*

*After Nichols (1972 and 1974).

An innovation on overwinter drawdown was used in Sweden to control plants mechanically. The water was drawn down and the plants allowed to freeze into the ice. Water was then introduced under the ice, floating the ice mass and mechanically removing the plants (Malueg, pers. comm.).

The antithesis of drawdown–flooding–has also been studied as a macrophyte control measure. Research was conducted in the Tennessee Valley Authority lakes (Penfound et al. 1945; Hall et al. 1946) on the feasibility of using flooding to control the aquatic and semi-aquatic plants used by the mosquito, *Anopheles quadrimaculatus*, for breeding grounds (the mosquito is an important malaria vector in southeastern United States). The authors did not, however, report on the effectiveness of their research. Studies have also shown that increasing water levels are effective in controlling cattails, *Typha latifolia* (McDonald 1955). Submersed vegetation may also change with increased water depth (Robel 1962), this change being most noticeable at the outer edge of the littoral zone.

Fish. Drawdown has been used to control fish populations by exposure of spawning areas and eggs, stranding of small fish in weed beds and shallow pools, and concentrating fish in open water areas thereby increasing their availability to anglers, commercial harvest and predation. The timing, duration and extent of a drawdown are considered important variables in determining effectiveness, although fish population control has been accomplished by both summer and winter drawdowns.

Timing was emphasized by Shields (1958). Carp *(Cyprinus carpio)* reproduction was controlled by coordinating drawdown with spawning activity; an attempt was made to lower the water levels immediately following each spawning period. As a result there was a decrease in the population of this species, accompanied by an increase in other species. The successful application of this procedure, however, necessitated careful analysis of fish gonadal development and climatic conditions.

The importance of degree of drawdown was illustrated by Bennett et al. (1969). A 3 m fall drawdown (35% decrease in surface area) at Ridge Lake, Illinois, USA reduced the bluegill *(Lepomis macrochirus)* population from over 50,000 to under 20,000, whereas a 4.6 m drop (69% decrease in surface area) caused the population to decrease to 5,000-10,000. The effect will no doubt vary from lake to lake–for example at Murphy Flowage, Wisconsin, USA a 50% decrease in surface area had no measurable effect on bluegill abundance (Snow 1971)–but Bennett's study suggested the level of management that can be attained in some lakes.

Where drawdown is not implemented during spawning activity the most important mechanism of fish population reduction may be predation. Heman et al. (1969) found that thinning resulted from entrapment in weed beds and stranding in shallow pools in addition to predation, but Pierce et al. (1963) presented information indicating predation was the most influential factor. Drawdown exerted the strongest effect when accompanied by either mechanical removal of a problem species or a large population of predators. Also, in many instances food consumption and/or growth of predator species has increased during drawdown (Snow 1971; Heman et al. 1969; Beard 1971). These findings imply that the success and consequences of future water manipulation programs may be more predictable with a knowledge of: (1) the species composition of the predator population, (2) the population size of predator species in comparison to species to be controlled, and (3) the period of peak feeding and metabolic activity for the predator species present in the lake. An understanding of these variables would affect the season and duration of drawdown and indicate whether or not a supplemental control technique would be necessary.

Although certain pelagic species such as gizzard shad *(Dorosoma cepedianum)* may be unaffected or benefited (Wood and Pfitzer 1960; Lantz et al. 1964), drawdown has often improved the fish population where littoral species are involved. Therefore, drawdown appears to have high utility as a fish control measure; however, there is a need for improved comprehension and quantification of cause-and-effect relationships.

Habitat Manipulation

Algae. Algal population density is a function of numerous interacting environmental variables; light, temperature and nutrients are perhaps the most basic. Many schemes have been devised to manipulate these factors in order to control nuisance algal blooms (e.g. the various in-lake nutrient limitation techniques and the aeration/circulation methodologies). Most of these procedures are discussed elsewhere in this report. Two additional ones that have potential for algal control involve solar illumination and physical washout.

Although dyes will be discussed in terms of macrophyte control (below), the introduction of these materials into the epilimnion will also influence the phytoplankton. Buglewicz (1972) studied the effect of textile dyes in Teton Pond, Nebraska, USA. Treatment resulted in a shift in dominance from blue-green species to green algae and diatoms; this was accompanied by a greatly reduced rate of C^{14} uptake. These findings are noteworthy and suggest that this is an area deserving further investigation.

The algal population dynamics within a lake can also be altered by increasing the washout rate without changing the water quality. High flushing rates apparently reduce phytoplankton standing crops and favor nannoplankton species having a more rapid growth rate. This finding was reported for Marion Lake (Canada) with a retention time as short as 2.5 days (Dickman 1969) and for some Scottish lakes (United Kingdom) where the critical retention time was estimated at about 10 days (Brook and Woodward 1956). In addition, Ridley (1970) reported on the ability to control troublesome blooms of algae in two English reservoirs (United Kingdom) by maintaining flushing rates of approximately 12 days. Nuisance growths of *Microcystis aeruginosa* occurred when the retention time increased to 40 days. Also, investigations associated with the dilution/flushing projects at Green and Moses lakes (Washington, USA) determined that flushing rates of less than two and four days, respectively, would have controlled problem algal species purely by physical washout (Shepherd 1968; Welch et al. 1972a). Algal control might be achieved by the diversion of nutrient-rich waters into a lake, thus creating near river conditions.

Macrophytes. Various procedures have been implemented to limit macrophytes by light control and bottom treatments. Management activities that reduce light intensity or change the spectral qualities of the light can be used to control plant growth. Likewise, modification of the substrate can prohibit rooting of the plants.

Light has been limited by the use of dyes. A black dye called nigrosine was used to convert the water into a weak ink, a method Bartsch (1954) found only partially successful. The dye was nontoxic to fish, but had the disadvantage of making the water unattractive until the dye faded. Eicher (1947) treated two ponds (0.2 and 1.2 ha) and two lakes (4.5 and 81 ha) in Arizona, USA with aniline dyes. He noted a great reduction in visibility after the dye applications and the greatest effect of the dye upon the rooted aquatics was noted the year following treatment, when normally semi-emergent weeds failed to reach the surface. There are, however, no reports of its use in recent literature. A new dye* has recently been introduced on the market (Wilson, pers. comm.). No scientific publications have evaluated the product, but based on manufacturer specifications, the product appears worthy of investigation and is being studied by the Inland Lake Renewal Project in a farm pond in Wisconsin, USA (Nichols, pers. comm.).

Light penetration was also cut off by floating 8 mil black plastic sheeting on top of farm ponds with weed problems in Iowa, USA. Good control of pondweeds (*Potamogeton* spp.) and coontail (*Ceratophyllum demersum*) was obtained after 18-26 days of coverage. Experiments to control *Chara vulgaris* and emergent species met with failure (Mayhew and Runkel 1962).

Although dredging and sediment consolidation techniques have been dealt with previously, it should be briefly mentioned that both techniques can be used to deepen a lake to depths below the photic zone, thus limiting the light for plant growth. Dredging can also be used to remove nutrient-rich sediments and alter the textural consistency of the substrates.

The use of sand or gravel blankets with or without underlying black plastic sheeting was used to control macrophyte plants in Marion Millpond, Wisconsin, USA (Born et al. 1973b) and Windfall Lake, Wisconsin (Nichols 1974). This technique was effective in controlling plants over the short term of the project study. The longevity of such efforts has not yet been ascertained. Black plastic was used to line drainage and irrigation ditches in the United Kingdom to control weeds and increase hydraulic capacities with apparently satisfactory results (Great Britain 1959). The method is also recommended for controlling weeds and constructing swimming beaches in farm ponds (Klingbiel et al. 1968). Theoretically the method does two things: (1) if only a sand or gravel blanket is used, the substrate can be significantly altered, making rooting much more difficult and (2) an impermeable sheet under the blanket limits the transport of nutrients from the original lake bottom into the rooting zone of the plant. Present information suggests that further research and long-term monitoring are desirable in this area.

Fish. Many types of physical control techniques that are now practiced will affect fish habitat. Most of these have been discussed elsewhere in this report (e.g. deepening, aeration, and macrophyte harvesting). Two additional procedures that have been used in attempts to directly influence fish population dynamics are: (1) modification of spawning areas, and (2) installation of brush shelters. Neither of these have been thoroughly evaluated in terms of eutrophic lake restorations.

Fish reproduction has been controlled by either construction or destruction of spawning grounds. Johnson (1948) referred to several lakes in Illinois, USA in which the spawning areas were repeatedly trampled or dragged to prevent reproduction. Apparently the technique was successful, but he stressed that "good results seem assured only in small waters where all spawning areas can be covered". Conversely, Ryder (1970) indicated that artificially constructed spawning beds have been used with limited success in the management of some warm water fish species. He felt that the necessary technique modifications will result from a better understanding of the specific spawning requirements for a particular species. Nevertheless, von Geldern (1966) concluded that this approach was of little value for large waters in California, USA.

Brush shelters have been used in fisheries management to provide a place of refuge from predation, increase the fish food production and/or improve the harvest by attracting sport fish. Hubbs and Eschmeyer (1938) discussed various types of construction and installations, although the list of potential materials and designs is endless. Despite their long history of use, the only documented evaluations were conducted on infertile lakes (Rodenheffer 1939). In terms of improving the sport fish harvest in reservoirs with fluctuating water levels, Jenkins (1970b) considered brush shelters a fairly valuable management tool, but Calhoun (1966) felt that usage had generally been unsatisfactory. Both authors indicated that cost was a problem with this technique.

Neither of these methods of habitat manipulation can presently be recommended for a program of lake restoration. Substantive investigations have not been conducted and the opinions regarding past experiences are conflicting. Spawning area modifications have perhaps the most potential and merit further study, but there is no assurance of an eventual procedure that compares well with others now available.

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*Trade name—Aquashade.

Chemical Controls

Noxious algal blooms, dense growths of macrophytes and unbalanced fish populations often impair or preclude various recreational and domestic uses of surface waters. Of the numerous techniques which have been employed as control measures, chemical treatment has been the most widely used method. Chemical treatment has the greatest utility and justification in highly eutrophic lakes in which the nutrient supply cannot be effectively controlled and where other management alternatives are infeasible. Based on intent of usage, chemical controls can be divided into three categories: (1) algicides, (2) herbicides and (3) piscicides.

Algicides

The control of nuisance algal blooms can be achieved with a variety of chemicals. Algicides registered for use in or on water by the U.S. Environmental Protection Agency (EPA) are presented in Table 9 (McClure, pers. comm.; received June

TABLE 9. Algicides Registered by the Environmental Protection Agency, USA

Chemical	Dosage As Active Ingredient	Sites, Types of Weeds, Limitations
Acrolein (Aqualin) (2-Propenal)	1.2 - 7.2 mg/l	Lakes, ponds; algae, submersed weeds. Do not apply to water used for domestic purposes. May use for irrigation and farm uses 3 days after application.
	1.2 - 46.0 mg/l	Irrigation canals and drainage ditches. Do not use treated water for irrigation until concentration falls to 13.8 mg/l.
Copper sulfate .5H_2O	0.05 - 2.3 mg/l (pentahydrate) (exempt)	Lakes, ponds, potable water reservoirs; algae.
Copper sulfate chelated	1.0 - 4.0 mg/l (pentahydrate) (exempt)	Lakes, ponds, potable water reservoirs; algae.
	1.6 - 12.0 mg/l (pentahydrate) (exempt)	Industrial ponds.
Dehydroabietylamine acetate	0.4 - 0.68 mg/l	Lakes and ponds; algae. Do not apply to water used for domestic purposes.
	1.0 - 12 mg/l	Irrigation canals, ditches; algae. Do not use treated water on crops.
Dichlone (Phygon) (2, 3-Dichloro-1,4-naphthoquinone)	0.025 - 0.055 mg/l	Lakes, ponds, canals; certain bloom producing blue-green algae. Do not use in potable water.
Diquat (6, 7-Dihydrodiprido [1, 2-a:2', 1'-C] pyrazidiinium)	0.5 - 1.5 mg/l cation	Lakes, ponds, ditches, laterals; algae. Do not use treated water for animal consumption, swimming, spraying, or irrigation until 10 days after treatment. Do not use treated water for drinking purposes until 14 days after treatment.
Endothall (Dimethylalkylamine)	0.05 - 0.83 mg/l	Lakes and ponds; algae. Do not use treated water within 7 days at 0.3 mg/l, 14 days at 3.0 mg/l.
Sodium pentachlorophenate	4.5 - 18 mg/l	Paper mill supply impoundments; algae.

1973). Some of these materials could, however, be toxic to all aquatic life in the treated–and adjacent–area if indiscriminately used at the maximum dosage rate listed. The specific rate selected for a particular body of water should be arrived at only through professional judgment or experience, ideally involving limited in-situ testing (Mackenthun, pers. comm.).

Additional chemicals that have been used at least experimentally but are not currently registered for aquatic use by the EPA include:

Algaedyn (generic name unknown)
Algaekleer (generic name unknown)
Atrazine (2-Chloro-4-[isopropylamine]-6-[ethylamino]s-triazine)
Copper sulfate and silver nitrate (CA350)
Cuprose (generic name unknown)
Dichlobenil (2,6 Dichlorobenzonitrile)
Diuron (Karmex) (3- [3,4-Dichlorophenyl]-1, 1-dimethylurea)
Fenuron (Urab) (TCA) (N,N,-Dimethyl-N'-phenyluronium trichloroacetate)
Monuron (3-[P-Chlorophenyl]-1, 1-dimethylurea)
Organic mercury compounds (Phenyl mercuric acetate, Algimycin-200, Algimycin MT 4)
Paraquat (1,1'-Dimethyl 1-4, 4'-bipyridinium salts)
Potassium permanganate
Prometryne (Caparol) (2,4-Bis[isopropylamino]-6-methylmercapto-s-triazine)
Quaternary ammonium compounds (Cetyl trimethyl ammonium bromide, Algistat, Exalage L.C., Armazide)
Silver nitrate
Silver sulfate
Simazine (2-Chloro-4,6-bis[ethylamino]-s-triazine)
2,3 Dichloronapthoquinone (2,3-CNQ)

Algicide applications normally include just the shoreline, but entire lakes are sometimes treated when costs are not prohibitive. In either case it is often necessary to treat several times during the growing season for adequate control of algae. Shoreline treatments on a weekly basis are not uncommon, but the degree of success has been highly variable. Windblown accumulations from other areas of the lake frequently negate benefits from this type of treatment. When entire lakes are treated the results are usually longer lasting. Nevertheless, the degree of control depends on climatic conditions, water quality and other variables. Caution must also be exercised with total treatments so that dissolved oxygen levels are not critically reduced when decomposition of algal cells occurs.

Copper sulfate has long been the principal chemical used in controlling algae. Fitzgerald (1971) reported that over nine million kilograms of copper sulfate are used annually for algal control. In the State of Wisconsin (USA) alone, a total of over 680,000 kg were applied to 130 lakes between 1950 and 1969 (Lueschow 1972).

Methods of application range in sophistication from towing a bag of crystals behind a rowboat to extensive aerial applications. Domogalla (1926), in one of the earliest papers on copper sulfate treatment, indicated that spraying is more effective and economical than the bag-dragging method. He found the types of algae controlled by copper sulfate were *Microcystis, Coelastrum, Pediastrum, Fragilaris, Aphanizomenon, Hydrodictyon, Scenedesmus,* and *Anabaena.*

The effectiveness of copper sulfate is severely limited in hard water lakes because the calcium carbonate combines with the copper sulfate to form an insoluble precipitate of copper basic carbonate (O'Donnell 1943). For each 1.72 mg/l of calcium carbonate in the water, 1 mg/l of copper sulfate is removed. Chelated $CuSO_4$, which does not precipitate as readily, is now often used in hard water lakes. The effectiveness of chelated copper sulfate was shown at Lake Delavan, Wisconsin, USA a hard water lake with a blue-green algae problem. A chelated copper algicide was used at rates of ½ to 1¼ gal/acre (about 4.7 to 12 l/ha). Six treatments were made in 1969 and eight in 1970. The first four treatments reduced the population of *Anacystis* to nearly zero (American City Magazine 1971).

Further discussion of the past usage of copper sulfate and other algicides was presented by Mackenthun (1969) and Goldman (pers. comm.) has reported on imaginative, recent experimentation in which attempts are being made to decrease periphyton growth on concrete by using concrete–CuSO4 mixtures. Individual experiences using the various algicides are described in Part Two.

Herbicides

Macrophytes can generally be controlled quite readily with herbicides if the proper herbicide is selected and correctly applied. For many years prior to the 1960's, sodium arsenite was the only herbicide used in significant amounts to control macrophytes. In 1961 nearly 91,000 kg were used in Wisconsin, USA lakes (Lueschow 1972). More recently, degradable organic herbicides have been developed that are relatively safe, easy to use and equally effective.

Table 10 is a list of herbicides registered by the U.S. EPA for controlling macrophytes within lakes (McClure, pers. comm.; received June 1973). And Table 11 indicates those herbicides registered with EPA for use on mud bottoms after drawdown of the water body (McClure, pers. comm.; received June 1973). The specific dosage rate used for a particular body of water must be chosen carefully. Professional expertise with experimental in-situ testing in a limited area is needed to arrive at the dosage rate that will control target species without undesirable side effects (Mackenthun, pers. comm.; Hasler, pers. comm.). This will also entail consideration of possible other uses of the treated water (e.g. municipal water supply and agricultural usage).

Other chemicals that have been used for macrophyte control include:

Ammonia
Bromacil (5-Bromo-3-sec-butyl-6-methyluracil)
Copper sulfate
Dichlorobutyric acid and chlorinated fatty acids
Diuron (3-[3,4-Dichlorophenyl]-1, 1-dimethylurea)
Fenuron (TCA) (Urab) (N,N,-Dimethyl-N'-phenyluronium trichloroacetate)
HTH (generic name unknown)
Ortho-dichlorobenzene
Paraquet (1,1'-Dimethyl-4,4'-bipyridinium salts)
Simex (generic name unknown)
Sodium arsenite
Sodium hypochloride
2,4,5-T (2,4,5-Trichlorophenoxyacetic acid)

Herbicides are effective either immediately on contact or through systemic action. Treatment is often around the margins of lakes, although entire bodies of water have been treated. Sometimes only channels are treated to allow navigation to deeper water areas. Usually one treatment is sufficient for a growing season, but on occasion it has been necessary to again treat areas where control was not satisfactory or where subsequent growth interfered with desired uses. Also, nuisance algal blooms will sometimes follow extensive macrophyte eradications as nutrients are released from the decaying plants. *Chara* sp. can invade areas "opened up" by macrophyte eradication, often resulting in more undesirable conditions. Herbicide applications in general and some of the ramifications are discussed by Mackenthun (1969), Mackenthun et al. (1964) and elsewhere.

In summary, herbicides can and are being used effectively but the need for caution in applying any pesticides, whether to the aquatic or terrestrial environment cannot be overemphasized. In many cases inadequate information exists on the effects of herbicides and their degradation products on nontarget species and water quality. Only registered herbicides should be used and label restrictions must be followed closely to avoid unnecessary hazards to the ecosystem and to public health and welfare. Where necessary, state and local permits

TABLE 10. Herbicides Registered by the Environmental Protection Agency, USA for In-Lake Treatment of Macrophytes

Chemical	Dosage As Active Ingredient	Sites, Types of Weeds, Limitations
Acrolein (Aqualin) (2-Propenal)	1.2 - 7.2 mg/l	Lakes, ponds; algae, submersed weeds. Do not apply to water used for domestic purposes. May use for irrigation and farm uses 3 days after application.
	1.2 - 46.0 mg/l	Irrigation canals and drainage ditches. Do not use treated water for irrigation until concentration falls to 13.8 mg/l.
Amitrole (3-Amino-s-triazole)	8 - 20 lb/acre (9-22.4 kg/ha)	Site unspecified–cattails (*Typha* sp.). Do not contaminate water used for domestic or irrigation purposes.
Amitrole - T(3-Amino-s-triazole + ammonium thiocyanate)	6 - 10 lb/acre (6.7-11.2 kg/ha)	Drainage ditches, marshes; cattails (*Typha* sp.). Do not apply where water may be used for domestic or irrigation purposes.
	1 - 1.5 lb/acre (1.1 - 1.7 kg/ha)	Drainage ditches, marshes; water hyacinth (*Eichornia crassipes*). Do not apply where water may be used for domestic or irrigation purposes.
Dalapon (2,2 dichloroproprionic acid)	11 - 22 lb acid/acre (12.3 - 24.7 kg/ha)	Drainage ditches, spot treatment; cattails (*Typha* sp.).
	10 - 15 lb (4.5 - 6.8 kg) 100 gal. water (379 l)	Do not contaminate water used for irrigation or domestic purposes.
Dichlobenil (Casoron) (2, 6-Dichlorobenzo-nitrile)	10 - 15 lb/acre (11.2 - 16.8 kg/ha)	Lakes, ponds; submersed weeds. Apply to water surface. Do not use treated water for irrigation or for human or livestock consumption. Do not use fish for food or feed within 90 days after treatment.
Diquat (6, 7-Dihydro dipyrido [1, 2-a: 1′-C] pyrozinediium dibromide)	2 - 4 lb cation/acre (2.2 - 4.5 kg/ha)	Lakes, ponds, ditches, laterals; submersed weeds. Do not use treated water for animal consumption, swimming, spraying, or irrigation until 10 days after treatment. Do not use treated water for drinking purposes until 14 days after treatment.
Diquat	1 - 1.5 lb cation/acre (1.1 - 1.7 kg/ha)	Lakes, ponds, ditches, laterals; floating weeds. Do not use treated water for animal consumption, swimming, spraying, or irrigation until 10 days after treatment. Do not use treated water for drinking purposes until 14 days after treatment.
Diquat	2 lb cation/acre (2.2 kg/ha)	Lakes, ponds, ditches, laterals; emersed marginal. Do not use treated water for animal consumption, swimming, spraying, or irrigation until 10 days after treatment. Do not use treated water for drinking purposes until 14 days after treatment.
Endothall (Dimethyl alkylamine)	0.5 - 2.5 mg/l	Lakes and ponds; submersed weeds, *Chara*. Do not use treated water within 7 days at 0.3 mg/l, 14 days at 3.0 mg/l.
	1 - 5 mg/l	Irrigation canals, drainage ditches, weeds. Do not use treated water within 7 days at 0.3 mg/l, 14 days at 3.0 mg/l, and 25 days at 5.0 mg/l.
Endothall (Dipotassium) · (Disodium)	0.36 - 3.5 mg/l	Lakes and ponds; weeds. Do not use treated water for irrigation or domestic purposes within 7 days.
Petroleum Solvents	1,000 mg/l	Irrigation and drainage ditches, inject into water. Do not contaminate water used for domestic purposes. Do not use treated water for irrigation until emulsion breaks down.
Silvex (2-[2,4-5-Tri-Chlorophenoxy] proprionic acid)	8 lb/acre liquid (9 kg/ha)	Lakes, ponds; emerged floating weeds.
	40 lb/acre granular (44.8 kg/ha)	Do not contaminate water intended for domestic, irrigation, or crop spraying purposes.
	2.2 mg/l liquid 40 lb/acre granular (44.8 kg/ha)	Lakes, ponds; submersed weeds. Do not contaminate water intended for domestic, irrigation, or crop spraying purposes.
Simazine (2-Chloro-4, 6-bis [ethylamino -s-triazine)	0.78 mg/l	Ornamental ponds. Do not use in water intended for domestic or irrigation purposes.
2, 4-D Dichlorophenoxy-acetic acid	2.4 lb acid/acre (2.7 kg/ha)	Lakes, ponds; floating weeds. Do not use treated water for domestic or irrigation purposes.
	43.5 lb acid/acre (48.8 kg/ha)	Lakes, ponds; submersed weeds (granular). Do not use treated water for domestic or irrigation purposes.
	6.0 lb acid/acre (6.7 kg/ha)	Lakes, ponds; emerged marginal weeds. Do not use treated water for domestic or irrigation purposes.
Xylene (Dimethyl benzene)	740 mg/l (exempt)	Irrigation ditches, inject into water. Treated water may be used for furrow or flood irrigation.

TABLE 11. Herbicides Registered by the Environmental Protection Agency, USA for Treatment of Exposed Lake Bottom

Chemical	Dosage As Active Ingredient	Sites, Types of Weeds, Limitations
Dichlobenil (2, 6 Dichlorobenzonitrile)	7 - 10 lb/acre (7.8 - 11.2 kg/ha)	Lakes, ponds; submersed weeds. Apply to exposed shore and bottom.
Diuron (3-[3, 4-Dichlorophenyl] – 1, 1-dimethylurea)	16 - 48 lb/acre (17.9 - 53.8 kg/ha)	Drainage and irrigation ditches. Drain off water, spray moist soil in ditch. Fill ditch and let stand 72 hours, then waste contained water before use of ditch. Do not contaminate domestic water.
Fenac (2, 3, 6-Trichlorophenylacetic acid)	15 - 20 lb/acre (16.8 - 22.4 kg/ha)	Lakes, drainage ditches; submersed weeds. Drain area and apply to exposed bottom. Do not use treated water for domestic purposes.
Monuron (3-[Chlorophenyl]-1, 1-dimethyl urea)	32 - 80 lb/acre (35.9 - 89.7 kg/ha)	Irrigation and drainage ditches; drain water off area, spray bottom, fill ditch and hold 72 hours, then waste contained water before use of ditch.
Xylene (Dimethyl benzene)	100 gal/acre (935 l/ha)	Ponds, canals; drain off water and spray vegetation. Do not refill for 5 days.

should be obtained prior to treatment. Extensive research is in progress to evaluate the environmental effects of available herbicides and to develop new, more specific and safer ones.

Piscicides

An excellent review of the use of fish toxicants has been prepared by Lennon et al. (1970). The authors identified over 40 materials that can be used in fishery management and classified them in four groups based on amplitude of effect: (1) fish toxicants, (2) piscicides-herbicides, (3) invertebrate controls–piscicides, and (4) pond sterilants–piscicides (Table 12). Few toxicants have, however, been investigated exhaustively and usage restrictions exist for most of these in regions where safety is a primary consideration.

The application of toxicants for fish control has reached a relatively high level of sophistication. Treatments can now be conducted for partial, selective and total removal of fish populations. Some ways in which toxicants have been used are:

(1) application to only the surface waters of a thermally stratified lake. The piscicide's activity can thereby be limited to the epilimnion and the fish inhabiting the deeper areas are able to survive. This technique was first used by Greenbank (1941).

(2) application to a particular area of a lake, such as a cove or bay. This method has sometimes been used to remove a percentage of the total fish population (Cooper et al. 1971), but more often has been directed against concentrations of a particular fish species. Carp *(Cyprinus carpio)* spawning areas have been treated during peak activity (Helms 1967; Wales 1942) and they have also been concentrated at other times by baiting with grain crops, such as corn (Buck et al. 1960).

(3) application to remove a certain species or group of species. Several of the toxicants are species selective, particularly when the concentration is limited to a certain range. This approach has often been implemented to control gizzard shad *(Dorosoma cepedianum)* populations (Bowers 1955; Zeller and Wyatt 1967).

(4) application to eliminate a particular age category. Various chemicals such as $CuSO_4$ and NaOH have been applied directly to the nests in an effort to destroy the eggs (Allison undated; Beyerle and Williams 1967; Jackson 1956). Low concentrations of some toxicants can be used to kill the younger, smaller fish with little injury to the adult population (Burress 1970). And, in some cases, a toxicant could be chosen to kill all the members of a species except the developing eggs (e.g. when using rotenone).

(5) application to remove the total fish population. This tactic has been employed more than any other.

The degree of success has varied greatly between techniques and individual treatments using a particular procedure (see Part Two). In terms of improvement in fishing, Stroud and Martin (1968), however, have provided some generalizations. In warm water lakes where a total fish kill was attempted, good fishing resulted for an average of five years following restocking. Partial treatment sometimes produced improved fishing for over three years, but one to two years was more common.

Although reclamation of fish populations by chemical treatment is held in high regard and is a widely practiced procedure, many attempts have met with failure. Eutrophic lakes are difficult to treat successfully and the applicators often do not take into consideration all of the known variables that can negate the attempt. Optimal conditions for the achievement of a complete kill using emulsified rotenone in Michigan, USA lakes were found to be: (1) rotenone concentration of at least 1.5 mg/l, (2) temperature of 15.5 to 20.5 C, (3) lake size of less than 8.1 ha, (4) maximum depth of 3.4 to

TABLE 12. Chemicals Employed as Fish Toxicants*

The chemicals tested or employed as toxicants for fish and other aquatic life can be listed roughly under four categories, according to principal uses in fishery management:

Fish toxicants

1. antimycin (Fintrol)
2. Bayluscide (Bayer 73)
3. benzene hexachloride
4. calcium carbide
5. callicarpone
6. copper sulfate
7. croton seed powder
8. cunaniol
9. Dibrom-malathion
10. endrin
11. ichthyothereol
12. malathion
13. polychlorpinene
14. rotenone
15. saponins
16. sodium hydroxide
17. sodium sulfite
18. Squoxin
19. TFM
20. Thanite
21. Thiodan
22. toxaphene
23. turpentine
24. other botanical toxins

Piscicides-herbicides

1. anhydrous ammonia
2. Aqualin

Invertebrate controls-piscicides

1. Baytex
2. DDVP
3. ethyl parathion
4. Guthion
5. methyl parathion
6. phosphamidon
7. thiometon

Pond sterilants-piscicides

1. calcium cyanamide
2. chlorine (calcium hypochlorite)
3. lime
4. rosin amine D acetate
5. sodium cyanide
6. sodium pentachlorophenate
7. tobacco waste

*From Lennon et al., 1970.

6.1 m, (5) shallows of 60 to 80% of total volume, (6) alkalinity of 150 to 200 mg/l, (7) pH of 8.0 or less and (8) minimum of marshes, dense weed beds, floating bogs, turbidity, springs, and soft bottom areas (Spitler 1970).

The water chemistry of a lake can change from day to day and Lennon et al. (1970) recommended an on-site bioassay prior to any treatment program; this procedure should eliminate the potential difficulties arising from the presence of any problematic water quality factors. Care must be taken, however, to treat all areas of a lake. Weed beds and spring inflow regions, especially, must be identified and given special attention. In addition, partial treatments have sometimes had mediocre results because of a failure to use a nonrepellent toxicant or to prohibit fish escape from the treated area (Crabtree 1967). Another important consideration is the duration of toxicity. For instance, Stringer and McMynn (1960) reported that toxic conditions have remained for four years following treatment with toxaphene.

Although piscicides are usually employed to improve unbalanced fish populations and fishing directly, their usage often yields water quality benefits. Excessive turbidity and the absence of macrophytes coincide with overabundant carp populations due to their rooting behavior during feeding (Threinen 1949). The effect of treatment on these parameters is rarely documented, but improvements are known to have occurred in some instances (Hemphill 1954; Bennett 1949; Evans 1954). Moreover, in highly eutrophic lakes there is a danger of excessive macrophyte growth after carp removal.

Lennon et al. (1970) have identified research needs in the area of piscicide treatment. The technique is now a commonly used, effective management practice, but much information and experimentation are still necessary. At the present time four factors should be considered essential to any lake restoration attempt using fish toxicants: (1) there should be a definite problem, (2) no other management approach should be feasible, (3) biological and chemical facts rather than economics should govern the choice of toxicants and (4) the application should be conducted by competent and well-trained personnel. Justifiable applications of biocides, the folly of overuse and the reasons for concern are discussed by Hasler (1973).

Biological Controls

The control of a particular problem species by manipulation of biotic interactions has been a much desired goal in recent years. Evaluation of biological controls has, however, been limited in extent with much of the testing conducted in the laboratory and experimental ponds. The techniques can be divided into three groups: (1) predator-prey relationships, (2) intra- and interspecific manipulation and (3) pathological reactions.

Predator-Prey Relationships

There have been several attempts to control the population of a problem species by predation. The inefficiency of the trophic conversion alone aids in management, because a great deal of energy is lost in the food conversion (typically 80 to 90%; Odum 1970). A much smaller biomass of predator can be supported by the original biomass of prey. Great care must be taken, however, so that one problem species is not being substituted for another problem species.

One of the natural ways in which algal populations are kept under control is through predation by zooplankton and fish species. It would therefore seem feasible to develop a scheme of in-lake control of algal blooms using one or more of these predators. Experimentation has thus far emphasized the manipulation of certain fish species with only limited success.

According to Prowse (1969) suitable plankton feeding fish species are *Tilapia mossambica* and its allies and the silver carp, *Hypophthalmichthys molitriz.* Also, *Mugil cephalus* has been used in Lake Kinneret, Israel. Prowse reported, however, that algae that have a prominent mucilage sheath, such as *Anabaena flos-aquae* or *Microcystis aeruginosa,* were not harmed by the digestive enzymes. Plankton feeding fish are able to graze off digestible algae species, but these are usually not the dominant species during an algal bloom.

A great amount of research has been expended in the predacious control of macrophytes. Undesirable plants have been converted into a variety of desirable, or at least innocuous, organisms at a higher trophic level. Predators include snails (Blackburn and Weldon 1965), crayfish (Dean 1969), nutria *(Myocastor coypus)* (Ehrlich 1969), waterfowl (Ehrlich 1969), fish (Avault et al. 1966) insects and other anthropods (Zeiger 1967; Carlson 1971; Baloch et al. 1972; Hawkes 1965) and aquatic mammals such as the manatee (Allsopp 1960). The most publicized of these animals is undoubtedly the white amur *(Ctenopharyngodon idella).* A considerable volume of literature is available on this fish and its possible use for aquatic weed control (e.g. Avault et al. 1966).

Although most of the animals mentioned have been used successfully on a local or regional basis, many of the techniques do not have applicability over broad geographical ranges. In some cases the problem arises directly from the animal's biological restrictions, but there is also a great deal of justifiable caution being exercised by ecologists about introducing exotic species into a new area. More biological predators will probably become available following thorough evaluation of natural predators and the tolerance ranges of exotic species.

There has also been much interest in the control of problem fish species through the stocking of predator populations. In this way, the high poundage found in eutrophic lakes can theoretically be channeled into valuable forms of fish flesh. Introductions have been made either to add a new species to the lake or to maintain a population with limited reproductive ability.

Well-documented studies are limited but the technique has apparently had little success, especially when littoral species are involved. Overabundant and/or slow-growing bluegills *(Lepomis macrochirus)* were not controlled by the stocking of: (1) largemouth bass *(Micropterus salmoides)* in an Ohio, USA lake (Clark 1964); (2) walleye *(Stizostedion vitreum)* and muskellunge *(Esox masquinongy)* in a Wisconsin, USA lake (Snow 1968); and (3) northern pike *(Esox lucius)* in two Michigan, USA lakes (Beyerle 1970). In addition, Wickliff (1948) indicated that the value of predator stocking was unproven and Threinen (1960) and von Geldern (1966) reported that the technique was seldom successful. Nevertheless, overabundant shad (*Dorosoma* spp.)–a group of pelagic species–have been reduced through the stocking of white bass *(Morone chrysops)* and striped bass *(Morone saxatilis)* (Jenkins 1970b and pers. comm.).

Despite its long history, the art of fish stocking in general is relatively unsophisticated. Much research in terms of numbers, size and time of introduction are still needed (Northcote 1970). Stocking rates have often been established on an areal basis, but this approach has little value for controlling a problem species. A successful predator stocking program must at least consider: (1) the food preference of the predators. Is the target species a definitely preferred food type? (2) the size of the prey. Are the predators large enough to feed on the size category to be reduced numerically? (3) the size of the population of target species. Can the predators be stocked in sufficient quantities to achieve the desired impact? and (4) the availability of the prey. Will prevailing conditions (e.g. excessive macrophyte growths) severely restrict the prey's accessibility? These concepts seem paramount to the intelligent application of this technique. A sound biological principle is involved and a few past experiences indicate potential, but existing guidelines for implementation are rudimentary at best.

There are two other management techniques under this category that merit brief discussion. First, fish predators include many organisms other than fish (e.g. snakes, turtles and a variety of invertebrates). Ryder (1970) referred to several situations where their control might benefit the fish population. Conversely, their introduction may in some cases be used to limit the abundance of a problem species. Secondly, although the introduction of various food species is widely practiced as a means of increasing fish production (Ryder 1970; Northcote 1970; Pirozhnikov et al. 1969), food supply management has not been evaluated from the standpoint of restoration of eutrophic lakes. Information is presently insufficient to judge the potential efficacy of these techniques; both are in need of much research and development in the future.

Intra- and Interspecific Manipulation

Algae, Macrophytes. Plant-plant interaction usually occurs at a level where they are competing for critical substances such as light or nutrients. Under this method of control, one plant species is manipulated in order to induce a limiting condition on another. Hopefully, the second plant is more desirable than the first.

In California, USA Yeo (1971) used the slender spikerush *(Eleocharis acicularis)* to form a sod-like growth that prevented the establishment of other rooted aquatics. He did not delve into the competitive mechanism, although the method worked successfully.

Certain types of algae and macrophytes are known to have an antagonistic relationship (Hasler and Jones 1949; Goulder 1969). Fitzgerald (1968, 1969a, 1969b), among others, maintained that higher aquatic plants and phytoplankton are in direct competition with each other for nutrient materials. This would seem to be a worthwhile area of investigation, but field application has not been forthcoming from research efforts. The growth of submerged weeds has been suppressed by adding fertilizer to the water, which stimulated algal growth, thereby causing light exclusion (e.g. Davison et al. 1962; Whitley 1964), but this technique has little utility in lakes originally degraded by overfertilization.

Fish. Experimentation in this area has followed two general routes: (1) sterilization or sex reversal and (2) selective breeding. Theoretically, both of these approaches have merit in terms of lake restoration. The first approach can potentially be used to limit the progeny of overabundant and/or undesirable species, whereas objectionable characteristics of a species can perhaps be alleviated by the other method.

Several procedures are being developed to sterilize or cause sex reversal in fish. Problems have been encountered with each technique, but eventually they may have utility for limiting procreative ability. Three groups of agents seem to have the most potential–androgens, chemosterilants and radioactive compounds. Androgens have been used to cause sex reversal in several fish species, but were unsuccessful against bluegills *(Lepomis macrochirus)*. The treatment schedule may, however, have been inappropriate in this experiment (Chew and Stanley 1973). Chemosterilants have produced sterility in many organisms. Although fish reproduction can be significantly reduced, complete sterilization has not yet been achieved (Stock and Cope 1969). The use of radioactive materials has been effective in sterilizing fish, but there are also some difficulties associated with this technique (Ulrikson 1969). All three of these groups are presently considered hazardous in some regions and cannot be applied directly to lake waters for management purposes, but the introduction of presterilized fishes has shown some experimental promise (Jenkins 1970b).

Some attempts have been made to produce a fish with more desirable attributes through hybridization or development of certain strains of a species. Ideally, the fish population could be improved through the introduction of this "new species," although complete removal of the resident population may first be necessary. Achievements have been minimal to date. A promising panfish hybrid was produced by Childers and Bennett (1967), but further testing was considered necessary. Hybridization experiments normally yield fish that either are infertile, exhibit characteristics similar to or in between those of the parent species, or produce progeny that resemble the original parents. Some studies have been directed at developing certain genetic strains which have characteristics well suited to a particular habitat. Results have been favorable for salmonids (Northcote 1970) but species that predominate under eutrophic conditions have received little attention.

None of these species manipulation techniques is ready for general application. The practicality and efficacy of in-lake treatments is still speculative, but preliminary studies have produced encouraging results and more experimentation seems well justified. An intensive testing and development program will be required, however, to fully explore the potential of these techniques.

Pathological Reactions

Algae. Parasitism naturally occurs in the algal population. Fungi have been reported infesting diatoms and desmids (Canter and Lund 1948; Lund 1971) and bacteria have been isolated that kill or lyse a variety of green and blue-green algae (Stewart and Brown 1969). However, controlling blue-green algal blooms by viruses probably offers a greater potential than other biological controls, because a virus is often species specific.

Safferman and Morris (1963) were the first to isolate a virus that infested blue-green algae. Several other viruses have since been identified. Table 13 lists the known viruses and their hosts. Although the control capability of a virus has been demonstrated by clear areas within a dense bloom of *Microcystis aeruginosa* in a reservoir (Goriushyn and Chaplinskaya 1966), only one deliberate in-lake treatment using a virus has been reported in the literature. Blue-green algal scums were apparently lysed as a result of spraying cyanophages on the surface of a lake in the USSR (Peelen 1969).

Macrophytes. Parasitic reactions, such as viral attack, is one biological method of inducing a fatal or at least a debilitating effect on a target species. A wide variety of

TABLE 13. Known Algal Viruses

Virus	Host	Reference
Ap–1	*Aphanizomenon flos-aquae*	Granhall 1972
AR–1	*Anabaenopsis raciborski* *Anabaenopsis circularis* *Raphidiopsis indica*	Singh and Singh 1967
C–1	*Cylindrospermum*	Singh and Singh 1967
D–1*	*Lyngbya, Plectonema, Phormidium*	Daft et al. 1970
G III*	*Lyngbya, Plectonema, Phormidium*	Padan et al. 1967
LPP–1*	*Lyngbya, Plectonema, Phormidium*	Safferman and Morris 1963
N–1	*Nostoc muscorum*	Adolph and Haselkorn 1972
SM–1	*Synechococcus elongatus* *Microcystis aeruginosa*	Safferman et al. 1969
---	*Anabaena variabilis*	Granhall and Hofsten 1969
---	*Microcystis aeruginosa* *Microcystis pulverea f. incerta* *Microcystis musicola*	Goriushyn and Chaplinskaya 1966

*The nomenclature is such that, generally, the first letter of the generic name of the host is used to describe the virus. It is very likely that D–1 and G–III are the same as the LPP–1 virus.

pathogens including viruses, rusts, smuts and other aquatic fungi (Zettler and Freeman 1972) attack macrophytes, but efforts to duplicate these natural attacks for management purposes are still in the investigatory stage or have been unsuccessful. Also, when dealing with pathogens, considerable caution is necessary if the range of plant types that they will attack is not known in detail. Potential pathogens from India and Central and South America are now being screened carefully for their effectiveness against macrophyte species in southeastern USA (Charudattan, pers. comm.).

Fish. Certain fish pathogens become more concentrated under eutrophic conditions (Collins 1970). Fish can usually coexist with these organisms without infection, but the crowding of fish populations–often the situation in fertile lakes–is a form of stress. Any type of stress combined with large numbers of pathogens and fish hosts can cause an outbreak of epidemics. Rogers (1969) referred to a few cases of poor bluegill *(Lepomis macrochirus)* condition due to the white grub *(Posthodiplostomum minimum)* and also to a lake that contained an unbalanced fish population, resulting from the negative effect of *Proteocephalus ambloplites* on largemouth bass *(Micropterus salmoides)* reproduction. Unlike plant pathological research, which is aimed at inducing infection, the control of pathogens has been emphasized in fish management.

Warm water fish culturists have conducted much investigation of pathogenic organisms and their control (Food and Agriculture Organization of the United States 1968), but experimentation in natural lake systems has been limited (Northcote 1970). Control techniques have been applied to parasite problems in oligotrophic lakes–Miller (1952) summarized attempts to control *Triaenophorus crassus* in several Canadian lakes with success in one case (Lawler 1961) and the *Diphyllobothrium norvegicum* infection rate was severely reduced in a Norwegian lake (Vik 1967)–but evaluations have apparently not been performed in terms of eutrophic lake restoration. Pathogen populations can be contained by antibiotics, flocculation, chlorination and/or host elimination. Flocculation, in particular, is used to precipitate phosphorus in lakes (p. 10), but the impact on the virus, bacteria, etc., communities has not been assessed during these treatments.

DISCUSSION AND SUMMARY

In general, lake restoration technology is in a "youthful" stage of development. Many techniques can be used with reasonable assurance of some success, but expectations have often exceeded the benefits and the side effects of some treatment approaches are poorly understood. Future studies must therefore be comprehensive, with more effort directed at the identification of important variables and the quantification of cause-and-effect relationships. Each lake appears to be a unique ecosystem; no technique can be applied indiscriminately to every situation. The types of treatment and degree of implementation can be intelligently chosen to produce the desired effect in a particular lake only through the utilization of predictive models.

Nutrient limitation schemes are presently considered the most desirable from the standpoint of long-range management. An effective lake restoration program might utilize a combination of these techniques (e.g. a method of curbing the influx with an in-lake procedure) to yield a rapid response, but research needs–the improvement of predictive abilities–will be met best by a single treatment, or at least step-wise application of the treatments. The studies that are essential adjuncts to any nutrient limitation program include:

1. Bioassays. What are the existing nutrient relationships? Will the treatment reduce the limiting nutrient, or will satisfactory results accrue by decreasing the supply of another nutrient?
2. Nutrient budgets. Sources need to be identified and quantitfied. What are the nutrient loadings before and after treatment? How do these loadings compare with Vollenweider's (1968) and other criteria?
3. Hydraulic and phosphorus residence times. Will improvements occur within a reasonable time period or will supplemental control techniques be necessary? Did the response materialize in accordance with predictions? If not, why not?
4. Nutrient exchange reactions. What are the pathways through the ecosystem? What factors influence the rate and degree of exchange? Present information indicates that the sediment-water interchange is especially important.

In some cases, application of a nutrient limitation program has been and will be impractical. The objective of making the lake more "usable" can, however, be fulfilled by means of a wide variety of mechanical, chemical and biological methodologies. Although recurring treatment is usually necessary, these techniques are often as effective and may sometimes have cost-benefit advantages. Studies accompanying this type of lake restoration attempt will depend on the individual situation (including particular lake conditions and type of treatment). The whole gamut of biotic and abiotic interactions within a lake ecosystem are potentially important. Projects to treat one problem have often created another.

Despite the research and refinement that are still needed, significant advances in lake rehabilitation have been made. Several factors influencing the successful application of existing techniques have been identified and thorough lake evaluations prior to deciding upon an appropriate technique should quickly increase the success rate and improve predictive capabilities in the future. Several theoretically sound techniques may soon evolve into highly effective restoration procedures. The development of improved engineering equipment will further enhance the cost effectiveness. In summary, present lake rehabilitation capabilities are substantial, although in need of extensive, well-documented testing, and future prospects for success in this realm of environmental management are very encouraging.

PART TWO:
INVENTORY OF LAKE REHABILITATION EXPERIENCES

The individual lake restoration experiences are presented and described briefly in this section. The compilation is organized according to the sequence shown in Table 14. The status and nature of each of the activities are also delineated in this table.

TABLE 14. Lake Rehabilitation Project Index

Legend
1 Wastewater Treatment
2 Diversion
3 Land Use Practices
4 Treatment of Inflow
5 Product Modification
6 Dredging for Nutrient Control
7 Nutrient Inactiviation/ Precipitation
8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

	Type of Lake Rehabilitation Scheme																
Location and Lake	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
AUSTRALIA																	
One (1) pond																0	
Albert Park																0	
AUSTRIA																	
Four (4) lakes																	
Rocksee				x		x											
Stubenbergersee				x		x											
Sulmsee				x		x											
Thabocher-See				x		x											
Six (6) lakes																	
Faaker See		0															
Klopeiner See		0															
Millstätter See		0															
Ossiacher See		0						x									
Weissensee		0															
Wörther See		0															
Goldegger See		0											0				
Obertrumer See							x										
Piburger See		0							0	0							
Reither See							0	0		0							
Zeller See		0															
BRAZIL																	
Americana	x	x															
BRITISH GUIANA																	
Several reservoirs and canals																	0
CANADA																	
Three (3) headponds																	
Beechwood	0																
Grand Falls	0																
Mactaquac	0																
Sixteen (16) lakes																0	
Twenty-seven (27) ponds																0	
#79													x				
Beauport				Indefinite technique; pre-treatment stage													
Buchanan													0				
Buffalo Pound								0									
Chain								0									
Chubb																0	
Copper																0	
Corbett													0				
Erie	0	0			0												
Fanshawe										0							
Huron	0	0			0												
Kootenay	0																
Mildred													0			0	
Millers													0				

TABLE 14. (continued)

Legend
1 Wastewater Treatment
2 Diversion
3 Land Use Practices
4 Treatment of Inflow
5 Product Modification
6 Dredging for Nutrient Control
7 Nutrient Inactivation/Precipitation
8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

	Type of Lake Rehabilitation Scheme																
Location and Lake	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Okahagan	0		0												0		
Ontario	0	0	x		0												
Pinks				Indefinite technique; pre-treatment stage													
Ramsey																0	
Rose		0													x		
Saint-Joseph	0	0															
Skaha	0																
Superior	0	0															
Thompson													0				
Wabanum															0	0	
Welland Canal							x										
Winnipeg reservoirs				x													
Yellow													0				
CZECHOSLOVAKIA																	
Irrigation canals																	0
Lubi																0	
DENMARK																	
Bagsvaerd Sø		0															
Lyngby Sø		0															
Pedersborg Sø		0															
Uttersler Mose		0					0										
EAST GERMANY																	
Arendsee		0								x							
Saidenbach				x													
FINLAND																	
Avhönjärvi														0			
Dämman										0							
Evijärvi									0						0		
Gallträsk		0				x								x			
Harinjärvi	0																
Illoistenjärvi		0				x	x								x		
Kakskerranjärvi		x								x							
Kiteenjärvi													x				
Lippajärvi										0							
Mytajärvi							0										
Pitkajärvi													x				
Ruokojärvi													x				
Särkinen													x				
Taattistenjärvi										0							
Tuusulanjärvi										x			0				
Vesijärvi		x											x				
FRANCE																	
Annecy		0															
Bourget		x															
Leman (Geneva)	0																
Morillon							x					x					
Nantua		x											x				
Paladru		x								x							
Parentis				Indefinite technique; pre-treatment stage													
Pas du Riot							0										
GREECE																	
Agras																	0
HUNGARY																	
Velence		0												0	0		
INDIA																	
Two (2) ponds																0	
Ooty						x				0							
IRELAND																	
Emy	x	x															
Ennell	x																
Garadice	x																
Inniscarra													0				
Leane	x																
Sheelin	0																
ISRAEL																	
Kinneret	0	0															0

TABLE 14. (continued)

Legend
1 Wastewater Treatment
2 Diversion
3 Land Use Practices
4 Treatment of Inflow
5 Product Modification
6 Dredging for Nutrient Control
7 Nutrient Inactivation/Precipitation
8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

	Type of Lake Rehabilitation Scheme																
Location and Lake	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ITALY																	
Trasmino																0	
JAPAN																	
Biwa		x															
Kasumi-ga-ura				Indefinite technique; pre-treatment stage													
Shirakaba		x									x						
Suwa		x															
MALAYSIA																	
Campus														0			
MEXICO																	
Chapala				Indefinite technique; pre-treatment stage													
NETHERLANDS																	
Two (2) reservoirs													x				
Brielse Meer				0													
Drontermeer	0					x											
Honderd en Dertig													x				
Loosdrechtse Plassen		0						x									
Maarsseveen													0				
Petrusplaat													x				
Veluwe Randmeer	x					x		x									
Veluwemeer North	0					x											
NEW ZEALAND																	
Many lakes		0	0												0	0	0
Two (2) lakes																	
Hayes		x						x									
Johnson								x									
Two (2) lakes																	
Rotoiti																0	
Rotorua																0	
Cosseys													0				
Rerewhakaitu		0	0														
NORWAY																	
Gjersjøen		0															
Kolbotnvatn													0				
PANAMA																	
Gatun															0	0	
POLAND																	
Two (2) lakes																	
Dlugie				Indefinite technique; pre-treatment stage													
Starodworski													x				
Kortowo										0							
Warniak																	0
PUERTO RICO																	
Several ponds																	0
Two (2) lakes																	
Carraizo	0								0						0		x
Cidra	0								0						0		x
RHODESIA																	
Three (3) lakes																	
Kyle																	0
Ngesi																	0
Umshandige																	0
McIlwaine	x														0	0	0
SINGAPORE																	
Sletar				x												0	0
SOUTH AFRICA																	
Gorengab													0				
Hartbeespoort	x																
Rietvlei	x	x															
Roodeplaat	x																
SWEDEN																	
Twelve (12) lakes				Indefinite technique; pre-treatment stage													
Seventeen (17) lakes	x	x															
Ange							0										
Balsjön		0															
Brunnsviken													0				
Edsviken													0				
Grycken	0												0				
Hagelsjön													0				

TABLE 14. (continued)

Legend
1 Wastewater Treatment
2 Diversion
3 Land Use Practices
4 Treatment of Inflow
5 Product Modification
6 Dredging for Nutrient Control
7 Nutrient Inactivation/Precipitation
8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

Location and Lake	Type of Lake Rehabilitation Scheme																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Hornborgasjön															0		
Järlasjön													0				
Kocktorpssjön						0								0	0		
Långsjön													0				
Långsjön							0										
Lötsjön							0										
Mälaren						0								0			
Norrviken		0															
Ösbysjön																	0
Råcksta träsk						x											
Ravalen															0		
Rönningesjön																	0
Södra Hörken							0										
Träsksjön													0				
Trehörningen						x									x		
Trummen						0											
Tullingesjön													0				
Uttran	0	x															
Växjösjön													0				
SWITZERLAND																	
Three (3) lakes																	
Biel	x																
Brienz	x																
Thun	x	x															
Bret													0				
Hallwil		0															
Inkwil		0						0							0		
Mauensee		0								0							
Pfaffikersee													0				
Rotsee		0						0									
Wilersee		0								0							
Zurichsee	0																
TUNISIA																	
Lake of Tunis	x	x				x		x	x						x		
UNITED KINGDOM																	
One (1) lake																0	
One (1) reservoir																0	
One (1) pond																	0
Five (5) lakes																0	
Six (6) ponds																	0
Blelham Tarn													0				
Chew Valley	x												x				
Eglwys Nungdd															0		
Farmoor													0				
King George VI													0				
Neagh	x																
Queen Elizabeth II													0				
Woburn Park Estate pond																	0
Wraysbury													0				
USSR																	
Several lakes							0										
One (1) lake																	0
One (1) reservoir																	0
Beloye													0				
WEST GERMANY																	
Two (2) lakes																	
Ammersee		0															
Staffelsee		0															
Two (2) lakes																	
Möllnersee												0					
Wittensee												0					
Four (4) lakes																	
Kochelsee		0															
Pilsensee		0															
Riegsee		0															
Worthsee		0															
Bodensee	0	0															

TABLE 14. (continued)

Legend					
	1 Wastewater Treatment	6 Dredging for Nutrient Control	9 Biotic Harvesting	13 Aeration and/or Circulation	17 Biological Controls
	2 Diversion	7 Nutrient Inactivation/ Precipitation	10 Selective Discharge	14 Lake Deepening	x Pre-treatment
	3 Land Use Practices	8 Dilution/Flushing	11 Sediment Exposure and Dessication	15 Other Physical Controls	0 Post-treatment or In Progress
	4 Treatment of Inflow		12 Lake Bottom Sealing	16 Chemical Controls	
	5 Product Modification				

Location and Lake	Type of Lake Rehabilitation Scheme																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Chiemsee	0			0													
Dümmer See	x	0		x		x											
Grebiner See							0			0		0	0				
Schleinsee													0				
Schliersee		0															
Spitzingsee		0															
Starnberger See		0															
Tegeler See				0		x								x			
Tegernsee		0															
Wahnbachtalsperre													0				
Wahnbachtalsperre				x													
WEST PAKISTAN																	
Haleji																	0
YUGOSLAVIA																	
Bled								0									
Palic		0				0											
USA																	
Fish ponds, Arkansas																0	
Irrigation ditches, Florida																0	
Small ponds, Georgia																0	
Farm ponds, Iowa															0		
Commercial waterways, Louisiana and vicinity															0		
Farm ponds, Missouri															0		
Farm ponds, Missouri																0	
Farm ponds, Missouri																0	
Farm ponds, Missouri																0	
Farm ponds, Missouri																0	
Farm ponds, Missouri																0	
Several lakes, New Hampshire																0	
Several lakes, New Hampshire																0	
Farm ponds, New York																0	
Hatchery ponds, West Virginia																0	
One (1) pond, Alabama																0	
One (1) lake, Alabama																0	
One (1) pond, Alabama																0	0
One (1) pond, Alabama																0	0
One (1) pond, Arizona																0	
One (1) pond, Colorado																0	
One (1) pond, Florida																0	
One (1) pond, Missouri																0	
One (1) pond, Wisconsin																0	
Two (2) ponds, Arizona															0		
Two (2) ponds, Georgia																	
∴BAC Pond															0		0
J. E. Taylor Pond															0		0
Two (2) lakes, Indiana																	
Elk Creek															0		
Springs Valley (Tucker)															0		
Two (2) ponds, Nebraska																	
Howard Roberts Pond							0										
Ray Jansen Pond							0										
Two (2) ponds, New Hampshire																	
Pond of Safety																0	
Swains Pond																0	
Two (2) lakes, North Dakota																	
Brush																0	0
Long																0	0
Two (2) lakes, Washington																0	
Two (2) lakes, Wisconsin																	
Corrine																	0
George																	0
Three (3) ponds, Alabama													0				
Three (3) ponds, Alabama																0	
Three (3) reservoirs, California																	
Alpine													0				
Bon Tempe													0				

TABLE 14. (continued)

Legend
1 Wastewater Treatment
2 Diversion
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4 Treatment of Inflow
5 Product Modification
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7 Nutrient Inactivation/ Precipitation
8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

Location and Lake	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nicasio																	
Three (3) lakes, Colorado																	
Granby		[illegible]															
Grand		[illegible]															
Shadow Mountain		[illegible]															
Three (3) lakes, Colorado and New Mexico																	
Alice																0	
Dorothy																0	
Maloya																0	
Three (3) ponds, Florida																	0
Three (3) ponds, Georgia																	
Cecil Jones Pond															[illegible]		
James Kimbro Pond															[illegible]		
L. B. Golden Pond															[illegible]		
Three (3) ponds, Mississippi																0	
Three (3) lakes, New Mexico																	
Mesa Hill																	0
Nutria																	0
Romah																	0
Four (4) reservoirs, Kentucky																	
Carpenter's																0	
Dewey																0	
Herrington																0	
Shanty Hollow																0	
Four (4) ponds, Massachusetts																	
Duck															0	0	
Jordan															0	0	
Massapoag															0	0	
Wedge															0	0	
Four (4) ponds, Michigan																	
Middle																0	
Mill																0	
Pleasant																0	
Podunk																0	
Four (4) ponds, New Hampshire																	
Ayers																0	
Bow																0	
Old College																0	
Swain's																0	
Four (4) lakes, North Dakota																	
Odland																0	
Raleigh																0	
South Lake Metigoshe																0	
Wolf Butte																0	
Four (4) lakes, Ohio																	
Caldwell													0				
Pine													0				
Steward Hollow													0				
Vesuvius													0				
Five (5) ponds, Alabama																0	
Five (5) lakes, Alabama																	
Barbour																0	0
Coffee																0	0
Crenshaw																0	0
Cullman																0	0
Pike																0	0
Six (6) ponds, Alabama																0	
Six (6) ponds, Georgia																	
Biggers																0	
Henry																0	
Hill																0	
Reynolds																0	
Slaughter																0	
Todd																0	
Six (6) lakes, Pennsylvania																0	
Seven (7) ponds, Maine																0	
Eight (8) ponds, Georgia															0	0	0
Eight (8) ponds, Georgia and Mississippi																0	
Eight (8) ponds, New Jersey																0	

TABLE 14. (continued)

Legend
1 Wastewater Treatment
2 Diversion
3 Land Use Practices
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5 Product Modification
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8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

	Type of Lake Rehabilitation Scheme																
Location and Lake	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Nine (9) ponds, Colorado and Oklahoma																0	
Nine (9) ponds and lakes, Georgia															0		
Nine (9) lakes, Wisconsin																0	
Ten (10) lakes and reservoirs, Oregon																0	
Thirteen (13) ponds, California																0	
Fourteen (14) lakes, Minnesota															0		
Fifteen (15) lakes, Michigan																0	
Sixteen (16) lakes, North Dakota																0	
Eighteen (18) ponds, Oklahoma																0	
Twenty (20) ponds and lakes, 6 states																0	
Twenty-one (21) lakes, Pennsylvania																0	
Twenty-six (26) ponds, Arkansas																0	
Twenty-six (26) lakes, North Dakota																0	
Over twenty-six (26) lakes, Michigan and Wisconsin															0		
Twenty-seven (27) lakes, Michigan																0	
About fifty (50) lakes and ponds, 19 states																0	
Fifty-six (56) ponds, Kentucky																0	
Eighty-four (84) lakes, Michigan																0	
Over one thousand (1,000) lakes, nationwide	x																
1860 Reservoir, Connecticut																0	
Alanconnie, Pennsylvania															0	0	
Alice, Florida		x							0						0		
Allen, Ohio																0	
Alma, Ohio															0		
Almanor, California															0	0	
Anacoco, Louisiana															0		
Annabessacook, Maine	x	0	x										0				
Apopka, Florida	x										x			x			
Arbor, Illinois													0				
Ardmore City, Oklahoma																0	
Arthur, Pennsylvania		0	0														
Ascarate, Texas																0	
Ashurst, Arizona															0		
Austin, Texas															0	0	
Babson, Massachusetts													0				
Backbone, Iowa																0	
Barcroft, Virginia			0											0			
Bass, Indiana															0		
Bass, Minnesota															0		0
Bear, New York													0				
Bear Camp, Georgia															0		
Beaver, Minnesota															0		
Beaver Dam, Wisconsin													0				
Beckers, Arizona																0	
Bedford, Pennsylvania													0				
Beulah, Florida																0	
Beulah, Wisconsin									0						0		
Big, Arizona													0				
Big, Missouri														0			
Big Alum, Massachusetts																0	
Big Bear, California																0	
Big Cedar, Wisconsin		x													0	0	
Billington, Massachusetts															0		
Black, Louisiana															0		x
Blackshear, Georgia																0	
Blackshear, Georgia																0	
Blue, Oregon		0													0		
Boddie, Alabama																0	
Boltz, Kentucky													0				
Bonito, New Mexico																0	
Booth (Standard), Michigan																0	
Boston Lot, New Hampshire																0	
Brainard, New Jersey														0			
Browns, Montana													0				
Buck, Minnesota															0		0
Buffalo, Texas																0	
Bugh's, Wisconsin																0	

TABLE 14. (continued)

Legend
1 Wastewater Treatment Diversion
2 Land Use Practices
4 Treatment of Inflow
5 Product Modification
6 Dredging for Nutrient Control
7 Nutrient Inactivation/ Precipitation
8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

	Type of Lake Rehabilitation Scheme																
Location and Lake	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Bussey, Louisiana															0		
Butterfly, Tennessee		0															
Cachuma, California													0				
Caddo, Texas and Louisiana															0		
Calhoun, Minnesota													0				
Canadarago, New York	x		x														
Capitol, Washington														x	0	0	
Carbody, Colorado																0	
Carlinville, Illinois														0			
Carlton, Florida												0					
Carlton, Maine																0	
Carnegie, New Jersey				0										0			
Carpenter, Kentucky																0	
Casitas, California													0				
Catherine, Arkansas																0	
Catherine, Arkansas															0		0
Cayuga, New York					x												
Chabot, California													0			0	
Chautauqua, New York															0		
Chickahominy, Virginia																0	
Chicot, Arkansas		x															
Chicot, Louisiana															0		
Clear, California								x					x		0	x	0
Clear, Louisiana															0		
Clear, Minnesota															0		
Clear, Wisconsin																	0
Cliff, Massachusetts																0	
Cline's, Oregon													0				
Cline's, Oregon							0										
Cobbett's, New Hampshire																0	
Cochrane, Wisconsin	0												x		0		
Collins, southern USA																0	
Conesus, New York		x			x												
Conneaut, Pennsylvania																0	
Conway, Arkansas																	0
Corpus Christi, Texas																0	
Cox Hollow, Wisconsin													0				
Creve Coner, Missouri														x			
Crystal, Minnesota						0											
Daggett, Michigan																	0
Davis, Mississippi																	0
Dead Lakes, Florida															x		
Deer Flat, Idaho																0	
Deer Island, Florida															0	0	
Delavan, Wisconsin																0	
Devils, Oregon		0															
Dewey, Kentucky																0	
Dewey, Kentucky															0		
Diamond, Oregon		0															
Dion, North Dakota													0				
Diversion, Texas																0	
Dollar, Michigan															0		
Duck, Massachusetts															0		
Eagle, Minnesota		0		0													
East, Montana																0	
East Okoboji, Iowa															0		
El Capitan, California													0				
Emerald, Michigan																0	0
Eola, Florida	0											0		0	0		
Escondido, California													0				
Eucha, Oklahoma															0		
Eufaula, Oklahoma													0				
Fall Hollow, Arizona		0															
Falmouth, Kentucky													0				
Fish, Utah		x															
Flathead, Montana	0																
Flora, Wisconsin															0	0	

TABLE 14. (continued)

Legend
1 Wastewater Treatment
2 Diversion
3 Land Use Practices
4 Treatment of Inflow
5 Product Modification
6 Dredging for Nutrient Control
7 Nutrient Inactivation/ Precipitation
8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

	Type of Lake Rehabilitation Scheme																
Location and Lake	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Fork, Illinois															0	0	
Fort Loudoun, Tennessee	0																
Fort Randall, South Dakota															x		
Fox, Wisconsin													0	0		0	
Franklin, Oklahoma																0	
Georgetown, Montana													0				
Giffin, Illinois																0	
Glen, New Hampshire																0	
Goose, Wyoming																0	
Granite Basin, Arizona															0		
Gravel, North Dakota													0				
Green, Washington								0						0			
Greenlee, Arkansas																	0
Greenville, New Hampshire													0				
Greenwood, New Jersey and New York																0	
Greenwood, South Carolina	x																
Griffin, Florida														0			
Hamilton, Arkansas																0	
Hamler, Ohio																0	0
Ham's Oklahoma													0				
Harriet, Minnesota	0				0												
Hemlock, Michigan													0				
Herman, South Dakota														0			
Heyburn, Oklahoma							0										
Hills Creek, Oregon			x							x							
Hiwassee, Oklahoma																0	
Hodges, California																0	
Hollingsworth, Florida															0		
Hooker, North Dakota													0				
Horseshoe, Wisconsin							0										
Hyrum, Utah													x				
Indian, Massachusetts															0		
Indian Brook, New York													0				
Indian Creek, California													0				
Indiana Univ. Reservoir, Indiana													0				
J. Percy Priest, Tennessee				Indefinite technique; pre-treatment stage													
Jacobs, Massachusetts														x	x		
Jennings, California													0				
Jordan, Massachusetts															0		
Jyme, Wisconsin														0			
Kegonsa, Wisconsin															0		
Kegonsa, Wisconsin		0															
Kezar, New Hampshire	x												0				
Koshkonong, Wisconsin															0		
Krause Springs, Wisconsin														0			
Ladora, Colorado						0											
Lafayette, California													0				
Lafourche, Louisiana															0		
Lake of the 4 Seasons, Indiana							0	0								0	
Lake of the Arbuckles, Oklahoma													x				
Larson, Wisconsin													0				
Lion's, Missouri			0											0			
Little Dixie, Missouri															0		
Little Dixie, Missouri			0														
Little Lake Tangerine, Florida									0								
Little Muskego, Wisconsin		0	0											0	0	0	
Lodge (Loon), Michigan													0				
Long, Illinois																0	
Long, Michigan														0			
Long, Wisconsin							0										
Long Reach, Maryland				0													
Loon, Michigan																0	
Lowell, Idaho															0	0	
Lower Blue, California																	0
Lower Hollywood, California													0				
Lower St. Regis, New York	0																
Lyman, Arizona																0	
Lyon County State, Kansas															0	0	

TABLE 14. (continued)

Legend
1 Wastewater Treatment
2 Diversion
3 Land Use Practices
4 Treatment of Inflow
5 Product Modification
6 Dredging for Nutrient Control
7 Nutrient Inactivation/Precipitation
8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

Location and Lake	Type of Lake Rehabilitation Scheme																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Madison lakes (5), Wisconsin															0	0	
Mansion, Illinois																0	
Marion, Minnesota															0		
Marion, Wisconsin												0		0	0		
Martis Creek, California							0										
Mary, Arizona													0				
Mascoma, New Hampshire		0														0	
Mattamuskeet, North Carolina															0		
Mead, Arizona		x		x													
Medina, Texas																0	
Mendota, Wisconsin		0															
Meridian, Washington		x															
Meridian State Park, Texas															0		
Metigoshe, North Dakota				Indefinite technique; pre-treatment stage													
Michigan, midwestern USA	0																
Middle, Montana																0	
Mill Creek, Oregon													0				
Mirror, Wisconsin													0				
Mittry, Arizona																0	
Mohawk, New Jersey															0		
Mondeaux, Wisconsin															0		
Monona, Wisconsin		0															
Montezuma ponds, New York															0		
Mc . ..eeka, Wisconsin																0	
Moses, Washington								x									
Mud, Michigan													0				
Murphy, Wisconsin															0		
Murphy, Wisconsin															0		
Murray, Oklahoma																0	
Muskegon, Michigan	x																
Needwood, Maryland				0													
Neff, Colorado																0	
Nevin pond (1), Wisconsin																	0
Nimrod, Arkansas														0	0		
Oakland, Illinois														0			
Occoquan, Virginia	x		x										0				
Oneida, New York		x															
Onized, Illinois															0		
Onondaga, New York	x				0												
Osceola, Florida							x										
Ottoville Quarry, Ohio													0				
Owasco, New York					x												
Oxbow, Illinois																0	
Parvin, Colorado													0				
Pasinkis, Michigan													0				
Penacook, New Hampshire																0	
Petrey, southern USA																0	
Pickerel, Wisconsin							0										
Plainsboro, New Jersey														0			
Pocono, Pennsylvania		x													0		
Pomps, Massachusetts														x			
Porters, Wisconsin																0	0
Powderhorn, Minnesota							0										
Province, New Hampshire																0	
Puddingstone, California													0				
Rankin, North Carolina													0				
Rays, Minnesota													0				
Richland, Wisconsin															0		
Ridge, Illinois															0		
Road Canyon, Colorado													0				
Roberts, New Mexico													0				
Rockwell, Ohio																0	
Rossmoor Sanitation Dam #1, California													0				
Rubberthread, Massachusetts													x		x		
Russell, Georgia										0							
Sallie, Minnesota	x								0								
Sammamish, Washington		0															

TABLE 14. (continued)

Legend
1 Wastewater Treatment
2 Diversion
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8 Dilution/Flushing
9 Biotic Harvesting
10 Selective Discharge
11 Sediment Exposure and Dessication
12 Lake Bottom Sealing
13 Aeration and/or Circulation
14 Lake Deepening
15 Other Physical Controls
16 Chemical Controls
17 Biological Controls
x Pre-treatment
0 Post-treatment or In Progress

Location and Lake	Type of Lake Rehabilitation Scheme																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
San Carlos, Arizona																0	
Sebasticook, Maine	0	0				x								x			
Section Four, Michigan													0				
Seminole, Georgia																0	
Serpent, Minnesota															0		0
Shagawa, Minnesota	0																
Shawnee (Pond Lick), Ohio						0	0										
Sheridan, South Dakota										0					0		
Sheridan County State, Kansas																	0
Skaneateles, New York					x												
Skatutakee, New Hampshire		0														0	
Slocum, Illinois																0	
Smith Mountain, Virginia	x			x													
Snake, Wisconsin							0	0									
Soda, Wyoming													0				
South Rod and Gun Club, Oklahoma															0	0	
Spauldings, Wisconsin																0	
Spring, Michigan													0				
St. Olaf, Minnesota															0		
State Rearing, Minnesota							0										
Steilacoom, Washington																0	
Stockade, South Dakota													0				
Stone, Michigan		0					x					x					
Stone Valley, Pennsylvania															x	x	
Storm, Iowa																0	
Sunshine Springs, Wisconsin														0			
Suttle, Oregon							x										
Tahoe, California and Nevada		0	0														
Tahoe Keys, California			0				0		0				0				
Talquin, Florida											x				x		
Taneycomo, Missouri				0												x	
TVA reservoirs, southeastern USA															0	0	
Teton, Nebraska															0		
Togus, Maine													0				
Tohopekaliga, Florida											0			0			
Traverse, Minnesota and South Dakota															0		
Trout, Florida														0			
Turtle, Minnesota															0		
Tuxedo, New York													x			0	
Twin lakes (2), Ohio		0					x										
Twin Valley, Wisconsin										0							
Upper Blue, California																	0
Upsilon, North Dakota													0				
Vancouver, Washington		x				x		x						x			
Veteran's Memorial, Wisconsin																0	
Volney, Minnesota															0		
Waccabuc, New York													0				
Waco, Texas													0				
Wahiawa, Hawaii													0				
Washington, Washington		0															
Waubesa, Wisconsin															0		
Waubesa, Wisconsin		0															
Waukomis, Missouri														0			
Wellington Reservoir No. 4, Colorado																0	
West, Montana																0	
West Lost, Michigan													0				
Whetzel, Illinois																0	
White, Michigan		x															
White, Wisconsin													0				
White Rock, Texas														x			
Whitewater, Nebraska																0	
Windfall, Wisconsin															0	0	
Wingra, Wisconsin															0		
Winnebago, Wisconsin															0		
Winnisquam, New Hampshire		x											0			0	
Winona, Minnesota		x											x			x	
Winter Park lakes (14), Florida															0		
Youngerman, southern USA																0	

LAKE NAME: One (1) pond
LOCATION: Brisbane, Australia
SURFACE AREA: 212 m^2
MAXIMUM DEPTH: 0.9 m

PROBLEM: Overabundance of macrophytes. **RESTORATION OBJECTIVE**: To test under field conditions the effect of a granular preparation of 2,4-D on a number of common macrophytes, and to determine in the laboratory the persistence of 2,4-D in the water by bioassay. **RESTORATION METHODOLOGY**: Aqua Kleen (20% w/w granular formulation of the butoxy ethanol ester of 2,4-D on 8-13 mesh "attoclay" granules) was used to treat two marginal strips, each 4.6 m^2 in area, in January, 1964. The material was sprinkled uniformly over the surface of the water at the rate of 0.024 kg/m^2 (48.8 kg 2,4-D acid equivalent/ha). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The submersed species *Ceratophyllum demersum, Hydrilla verticillata,* and *Potamogeton crispus* were completely destroyed. The rooted emergent species *Pontederia cordata* was injured but not seriously. This was also true for two of the free-floating species–*Salvinia auriculata* and *Lemna oligorrhiza.* Two other free-floating forms–*Pistia stratiotes* and *Azolla filiculoides* var. *rubra*–were killed initially but reinfestation occurred from untreated areas. Better control was anticipated using spraying to supplement application of the granular material. **REFERENCES**: Kleinschmidt (1969).

LAKE NAME: Albert Park Lake
LOCATION: Melbourne, Victoria, Australia
SURFACE AREA: 46 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of three species of macrophytes. **RESTORATION OBJECTIVE**: To control the growth of *Potamogeton ochreatus, Lepilaono australis,* and especially *Elodea canadensis* with herbicide treatment. **RESTORATION METHODOLOGY**: Acrolein was applied at a concentration of 10 mg/l during pretreatment trials. This was increased to 12 mg/l during actual treatment because of low water temperatures (10°C) and the great amount of vegetation present. The entire lake was treated by injection below the water surface from an airboat. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The initial treatment plus a retreatment six weeks later at 10 mg/l resulted in almost complete removal of *Elodea*. Annual treatment at a concentration of 5 mg/l was sufficient to give control in following years. **REFERENCES**: Bill (1969).

LAKE NAME: Four (4) lakes
Rocksee
Stubenbergersee
Sulmsee
Trabocher-See
LOCATION: Styria, Austria
SURFACE AREA: / MAXIMUM DEPTH:
Rocksee (7 ha) / 2 m
Stubenbergersee (35 ha) / 7 m
Sulmsee (7-10 ha) / 2-3 m
Trabocher-See (11 ha) / 7 m

PROBLEM: Eutrophication caused by bathing and sewage influx via the tributaries. Oxygen depletion in winter and summer. **RESTORATION OBJECTIVE**: To reduce the planktonic algal growth and biomass and to purify the tributaries. **RESTORATION METHODOLOGY**: Methods are under consideration for removal of bottom sludge and for purification of the tributaries. Costs have not been determined as yet. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: No results are available; the restoration projects are still in the pre-implementation stage. **REFERENCES**: Stundl (pers. comm.; current findings will be published in the 1973 yearbook of the Society of Natural Science in Styria, Austria).

LAKE NAME: Six (6) lakes
LOCATION: Kärten, Austria
SURFACE AREA: 1.1 to 19.4 km^2
MAXIMUM DEPTH: 30 to 140 m

PROBLEM: Algal blooms; turbid water; and oxygen depletion near the bottom. **RESTORATION OBJECTIVE**: To reduce the planktonic algal growth by stopping the phosphorus input. **RESTORATION METHODOLOGY**: A diversion canal is being constructed within the drainage basin of each lake. Wastewaters will be collected and, after biological treatment, discharged into the lake outflow. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: At this time results have not been published. **REFERENCES**: Sampl (pers. comm.).

	Surface Area	Maximum Depth	Construction Began	Cost
Faaker See	2.4 km^2	30 m	1970	$ 8,000,000 USA
Klopeiner See	1.1 km^2	46 m	1969	1,360,000 USA
Millstätter See	10.6 km^2	140 m	1968	14,400,000 USA
Ossiacher See*	13.3 km^2	46 m	1970	12,000,000 USA
Weissensee	6.6 km^2	99 m	1968	1,600,000 USA
Wörther See	19.4 km^2	84 m	1964-68	20,000,000 USA

* It is also planned to divert 3000 l/sec nutrient-poor water into the lake.

LAKE NAME: Goldegger See
LOCATION: Salzburg, Austria
SURFACE AREA: 3.7 ha
MAXIMUM DEPTH: 6.9 m

PROBLEM: Fishkills caused by dissolved oxygen depletion during autumnal overturn. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen conditions, preventing fishkills. **RESTORATION METHODOLOGY**: A sewage system was installed to eliminate the influx of domestic sewage and total aeration was initiated in September, 1965. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After three days of operation the lake was completely destratified and dissolved oxygen levels approached saturation. No decline in dissolved oxygen was observed during the destratification process, and the levels remained high after the compressor was shut down. No fishkills have occurred since the single aeration period, although no significant or permanent changes in water quality were noted. **REFERENCES**: Czernin-Chudenitz (pers. comm.), Czernin-Chudenitz (1967).

LAKE NAME: Obertrumer See
LOCATION: Salzburg, Austria
SURFACE AREA: ---
MAXIMUM DEPTH: 35 m

PROBLEM: Nuisance blue-green algal blooms caused by agricultural fertilizers. Oxygen depletion below 6 m during the summer. **RESTORATION OBJECTIVE**: To reduce the algal blooms and to improve the dissolved oxygen conditions. **RESTORATION METHODOLOGY**: A bay of the lake will be treated with aluminum sulfate to precipitate the phosphorus. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The project is still in the planning stage. **REFERENCES**: Czernin-Chudenitz (pers. comm.).

LAKE NAME: Piburger See
LOCATION: near Oetz, Tyrol, Austria
SURFACE AREA: 13.4 ha
MAXIMUM DEPTH: 24.7 m

PROBLEM: Slightly meromictic lake; loss of dissolved oxygen during autumnal overturn (in 1968 only 40% saturation prior to ice cover); and acute danger of winterkill. Eutrophication by sewage from restaurant and public swimming facilities. **RESTORATION OBJECTIVE**: To stop the nutrient and BOD input. To remove the oxygen demand and nutrients from the hypolimnion and thermocline by changing the outflow design. **RESTORATION METHODOLOGY**: During the winter of 1969-1970, snow was removed from 10% of the ice cover; all point sources of domestic sewage were also stopped until spring, 1970. In June, 1970 the discharge was composed mostly of water from the bottom of the lake (previously a surface water outlet). From June to mid-December about 10% of the lake's volume (100% of the volume below 18.8 m) was discharged through the special tube. Undesirable fish species and zooplankton were also harvested from the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After partial removal of snow from the ice the oxygen concentration in the upper 5 m rose well above critical values. At ice cover in 1970, 60% more oxygen was in the lake than in 1969; there was a further increase in the oxygen content in 1971 and 1972. There was no danger of fishkills during ice cover. Phosphorus elimination via the bottom water discharge tube and faunal harvesting was approximately twice as high as under unmanaged conditions. The diverted hypolimnetic waters averaged 15–25 mg P/m^3 as compared to 5–15 mg P/m^3 for the surface waters. The Piburger See is P-limited. **REFERENCES**: Pechlaner (pers. comm.), Pechlaner (1971).

LAKE NAME: Reither See
LOCATION: near Brixlegg, Tyrol, Austria
SURFACE AREA: 1.5 ha
MAXIMUM DEPTH: 8.2 m

PROBLEM: Dense phytoplankton (not blue-green algae) and bottom algae. Danger of fishkills during autumnal overturn. Worsening conditions despite domestic sewage diversion in 1961 and reduction of agricultural activities in the drainage basin. **RESTORATION OBJECTIVE**: To limit phytoplankton growth in the epilimnion and to remove hypolimnetic water (rich in nutrients, low or no dissolved oxygen, and high BOD and COD) from the lake. **RESTORATION METHODOLOGY**: In January, 1972 the surface water outlet was blocked and water was transported from the maximum depth in the lake to the stream channel beyond the former outlet via a plastic tube. In May, 1972 the lake was treated with $FeCl_3$ (approximately 6 mg Fe/l in the surface 2 m; $180 USA) for the precipitation of phosphorus, detritus, and algae. Surplus drinking water was also used for decreasing the hydraulic residence time. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Before treatment the Secchi disk water clarity was 0.7 to 0.9 m; within two weeks after $FeCl_3$ addition, water clarity increased to 2.7 m and it was twice as high in July, 1972 as in the previous July. The oxygen conditions in the hypolimnion during summer stagnation did not worsen in 1972 as compared to the previous summer. The dissolved oxygen level at autumnal overturn in 1972 was 9 mg/l; in 1971 the concentration had been 3 mg/l. A considerable quantity of phosphorus was released via the hypolimnetic discharge, but calculations are still incomplete. No adverse effects to the fish and crayfish were noted. **REFERENCES**: Findenegg (1972), Pechlaner (pers. comm.; several reports are in preparation).

LAKE NAME: Zeller See
LOCATION: Zell am See, Salzburg, Austria
SURFACE AREA: 4.6 km^2
MAXIMUM DEPTH: 68.4 m

PROBLEM: Nuisance blue-green algal blooms *(Oscillatoria rubescens). Coregonus* fishkills caused by oxygen depletion. Eutrophic conditions induced by sewage wastes. **RESTORATION OBJECTIVE**: To limit the planktonic algal growth and to improve the dissolved oxygen conditions by diversion of sewage wastes. **RESTORATION METHODOLOGY**: The diversion canal was constructed during 1955-72 at a cost of about $2,500,000 USA. The influx of sewage wastes was progressively decreased during the construction period. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Nuisance planktonic algal blooms were eliminated. The dissolved oxygen concentration in the hypolimnion was increased. Water clarity increased to a maximum of 10 m. Hygienic conditions became very good. **REFERENCES**: Liepolt (pers. comm.), Liepolt (1957, 1958, 1967).

LAKE NAME: Lake Americana
LOCATION: Atibaia Basin, São Paulo, Brazil
SURFACE AREA: 11.5 km^2
MAXIMUM DEPTH: 19 m

PROBLEM: Nuisance algal blooms; and fishkills. Eutrophic conditions induced by the influx of sewage and industrial wastes. **RESTORATION OBJECTIVE**: To maintain water quality adequate for recreation and water supply uses. To limit planktonic algal growth. **RESTORATION METHODOLOGY**: Several management plans are being considered for the removal of nutrients, foremost among these are the treatment of sewage and/or export to another basin. Concomitant with restoration planning is some recently created enforcement action. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Field studies are being carried on to more thoroughly understand the lake system and to identify all of the nutrient sources. Restoration techniques have not yet been initiated. **REFERENCES**: Amaral e Silva (pers. comm.), Amaral e Silva (1972).

LAKE NAME: Several reservoirs and canals
LOCATION: British Guiana
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Nuisance macrophyte growths interfering with water flow and usage. **RESTORATION OBJECTIVE**: To maintain macrophyte-free areas by methods more effective and less costly than herbicides. **RESTORATION METHODOLOGY**: Manatees *(Trichechus manatus)* were introduced to ingest the macrophytes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The waters were effectively cleared of macrophytes, especially *Cabomba aquatica, Anacharis, Leersia,* and *Utricularia. Nymphaea, Nelumbo, and Eichornia* were also fed upon heavily. **REFERENCES**: Allsopp (1960).

LAKE NAME: Three (3) hydroelectric headponds of the St. John R.
Beechwood
Grand Falls
Mactaquac
LOCATION: New Brunswick, Canada
SURFACE AREA / MAXIMUM DEPTH:
Beechwood (69.4 km^2) / 21 m
Grand Falls (86.5 km^2) / 6 m
Mactaquac (509.6 km^2) / 40 m

PROBLEM: Organic pollution from industrial wastes. Obnoxious odors; turbid water; and severely restricted recreational use of the water. **RESTORATION OBJECTIVE**: To reduce the BOD of the industrial effluents (nutrients not a problem); to eliminate the water quality problems; and to restore the salmonid fishery. **RESTORATION METHODOLOGY**: Advanced waste treatment is planned as part of a regional system. Implementation has begun. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Data has been and is being collected and processed for water quality modeling, cost/benefit analysis, and ecosystem analysis. Present information indicates that the largest BOD source (pulp mill; 70% of the loading) must be reduced by over 98%. Results are not yet available. **REFERENCES**: H. G. Acres, Ltd. (1971), Watt (pers. comm.).

LAKE NAME: Sixteen (16) lakes
LOCATION: British Columbia, Canada
SURFACE AREA: 4 to 780 ha
MAXIMUM DEPTH: ---

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To remove the fish population and restock. To determine guidelines for piscicide applications. **RESTORATION METHODOLOGY**: During 1956-1959 the lakes were treated with toxaphene at concentrations of 3 to 100 μg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The concentration of toxaphene necessary for effective control was influenced by species and size of fish, depth, stratification, flushing rate, and turbidity. Killing time was affected by concentration in an inverse relationship. Depth and thermal stratification inhibited dispersal of the piscicide and permitted fish survival. Detoxification was more rapid in the shallow basins. In turbid lakes incomplete kills occurred at concentrations of 20 μg/l, but in most lakes 6 to 7.5 μg/l was effective. **REFERENCES**: Stringer and McMynn (1960).

LAKE NAME: Twenty-seven (27) ponds
LOCATION: Ontario, Canada
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of aquatic vegetation. **RESTORATION OBJECTIVE**: To control macrophytes and algae with different concentrations of simazine, fenac and diquat. **RESTORATION METHODOLOGY**: Simazine was used in the 50% active wettable powder form and fenac (0.8 kg active/l) and diquat (0.24 kg active/l), in the liquid formulations. Application equipment included a hand operated rotary seeder, back-pack sprayer, and boat bailer for underwater injection. In some cases the water levels were lowered prior to treatment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Diquat provided for control of *Potamogeton pectinatus* and *P. filiformis*, although the long-term effectiveness was varied. *Chara* sp. and phytoplankton development were unaffected (one exception) by treatment. Diquat residues rapidly disappeared from the water. Fenac controlled several species of aquatic plants including *Chara* at rates of 2 and 3 mg/l, but was ineffective against filamentous algae, moss (*Drepanocladus* sp.), *Lemna minor*, and *Anacharis canadensis*. Phytoplankton numbers were sometimes reduced but total recovery was generally evident within 6-10 weeks. Treatment during drawdown at 22.4 kg/ha provided seasonal control of *Chara* sp. and *P. pectinatus* (treatment at 16.8 kg/ha was ineffective). In ponds that had a high hydraulic residence time, simazine controlled filamentous algae at 0.5 mg/l, submerged macrophytes at 1 mg/l, and *Chara* sp. at 2 mg/l for the entire season. Control was reduced or ineffective in other ponds. **REFERENCES**: Wile (1967).

LAKE NAME: Lake No. 79
LOCATION: southwest Manitoba, Canada
SURFACE AREA: 9.6 ha
MAXIMUM DEPTH: 2.5 m

PROBLEM: Summer fishkills due to excessive algal growth. **RESTORATION OBJECTIVE**: To maintain high dissolved oxygen concentrations during the maximum depletion period. **RESTORATION METHODOLOGY**: An aeration/circulation system will be installed in the lake, probably at mid-depth because a bottom-laid system would be detrimental to water quality. The proposed system is still under study. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Aeration will begin in July, 1973. **REFERENCES**: Barica (pers. comm.).

LAKE NAME: Lake Beauport
LOCATION: Quebec County, Quebec, Canada
SURFACE AREA: 85.5 ha
MAXIMUM DEPTH: 13.4 m

PROBLEM: Odors; macrophytes; fishkills; bacterial pollution; and algal growth. Also, the influx of road salt. **RESTORATION OBJECTIVE**: To limit algal growth and to control bacterial pollution. **RESTORATION METHODOLOGY**: Plans for the restoration of this lake have not yet been formalized. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Limnological studies have included a variety of parameters; however, the hydrodynamics involved precluded measurements of nutrient loadings and hydraulic residence time. The project is still in the planning stage; results are not available. **REFERENCES**: Bernard (pers. comm.), Rochon (pers. comm.; a technical report has been prepared).

LAKE NAME: Buchanan Lake
LOCATION: Dorset, Ontario, Canada
SURFACE AREA: 8.9 ha
MAXIMUM DEPTH: 13 m

PROBLEM: Hypolimnetic oxygen deficiency and high epilimnion temperatures during the summer. Poor salmonid fishery despite extensive stocking. **RESTORATION OBJECTIVE**: To maintain oxygen in the hypolimnion during the summer. **RESTORATION METHODOLOGY**: An artificial aeration system was installed in order to mix the lake and maintain oxygen at all depths. A compressor supplied air at 4.7 l/sec to a diffuser placed in the deepest part of the lake. Capital cost was about $1,000 USA, and operating costs were about $1/day. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The compressor ran continuously for 10 weeks during the summer of 1971 and was used again in the 1971-72 winter. Water quality rapidly improved after startup; the concentration of dissolved oxygen increased and concentrations of hydrogen sulfide, ammonia nitrogen, total phosphorus and iron decreased greatly. However, algal standing crop increased by 500-600%, and water clarity decreased by 50%. Zooplankton populations increased four-fold, but changes in bottom fauna and sediment chemistry were inconclusive, although aeration apparently reduced the amount of organic matter in the sediments. The system maintained an open area during the winter, about 110 m in diameter. Salmonids stocked in May, 1972 grew well and the lake has become attractive to anglers. **REFERENCES**: Brown et al. (1971), Brydges (pers. comm.).

LAKE NAME: Buffalo Pound Lake
LOCATION: near Moose Jaw, Saskatchewan, Canada
SURFACE AREA: 29.9 km^2
MAXIMUM DEPTH: 5.6 m

PROBLEM: Blue-green algal blooms and deoxygenation under ice cover. Eutrophy caused by agricultural drainage including feedlots; probably cottage owner septic tanks influential. **RESTORATION OBJECTIVE**: To limit blue-green algal growth and improve water quality (used as source of water for about 100,000 people). **RESTORATION METHODOLOGY**: The input of water from high quality, oligotrophic Lake Diefenbaker was accomplished via canal on an intermittent basis with the emphasis on winter flow. Inflow began in July, 1967 and has continued at highly variable discharge to the present. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The most marked change in water chemistry occurred during the first year; however, a gradual improvement continued in subsequent years. By 1972 total dissolved solids and major ion concentrations were halved; orthophosphate levels were reduced by 90%; nitrate nitrogen was down 80%; and ammonia nitrogen decreased by 60%. Blue-green algal populations (mostly *Aphanizomenon)* decreased more slowly and it was not until 1971 that they remained at sub-nuisance densities. The algal reduction has been accompanied by major increases in *Potamogeton pectinatus* in the shallows. **REFERENCES**: Hammer (pers. comm.), Hammer (1972).

LAKE NAME: Chain Lake
LOCATION: near Princeton, British Columbia, Canada
SURFACE AREA: 12.4 ha
MAXIMUM DEPTH: 5.5 m; 7.9 (1970)

PROBLEM: Heavy summer algal blooms and high water turbidity causing reduced recreational use. **RESTORATION OBJECTIVE**: To divert low nutrient water on an experimental basis in order to reduce algal blooms and prevent severe water discoloration during the summer recreational period. **RESTORATION METHODOLOGY**: Low nutrient water was diverted from a nearby creek system, $2.5-7.4 \times 10^5 m^3$ annually to a lake volume of $2.7 \times 10^6 m^3$. Cost for fluming, ditch, maintenance, and evaluation approached $30,000 USA for the period, 1965-1972. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: No significant effect on the physical, chemical, or biological conditions in the lake could be assigned to the diversion project, probably because the water volume available for diversion was too small and its entry into the lake was poorly located. **REFERENCES**: Ennis (1972), Northcote (pers. comm.), Northcote (1967), Taylor (pers. comm.), Taylor (1971, 1972).

LAKE NAME: Chubb Lake
LOCATION: Quesnel, British Columbia, Canada
SURFACE AREA: 67 ha
MAXIMUM DEPTH: 14.6 m

PROBLEM: Infestation of lake with undesirable fish species and severe reduction of gamefish production. **RESTORATION OBJECTIVE**: To severely reduce the undesirable fish species in a productive lake having extensive, associated marshy areas and to restock after one year with rainbow trout *(Salmo gairdnerii)*. **RESTORATION METHODOLOGY**: Pro-Nox Fish (2.5% rotenone) was applied at 1 mg/l to $3 \times 10^6 m^3$ of lake volume and also, to the outlet stream and attendant marshes. The total cost was $6350 USA (chemical, $4350; barrier, $500; operation, $500; and restocking in year one, $1000). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: All known species were distressed and dead within two hours. Because of the marshy nature of the lake, a complete kill was not expected; the rate of reinfestation and effects on trout populations are being monitored in addition to angler use and catch. Repetitive treatments 10 years apart may be practical and desirable. **REFERENCES**: Laidlaw (1972), Taylor (pers. comm.).

LAKE NAME: Copper Lake
LOCATION: Antigonish and Guysborough Counties Nova Scotia, Canada
SURFACE AREA: 21.6 ha
MAXIMUM DEPTH: 15 m

PROBLEM: Unbalanced fish population; overabundant, undesirable fish species. **RESTORATION OBJECTIVE**: To selectively remove the undesirable fish species. **RESTORATION METHODOLOGY**: Ground derris root (5% rotenone) was applied to the littoral zone of the lake out to a depth of 3 m. About 5.6 ha of the lake were treated by spray application to give a concentration of 0.57 mg/l. Treatment occurred each summer, 1948 through 1952. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: By the fifth year of partial poisonings, the golden shiner *(Notemigonus crysoleucas)*, yellow perch *(Perca flavescens)*, and northern creek chub *(Semotilus atromaculatus)* populations were eliminated from the lake. Other species were killed but were able to at least partially replenish themselves. Few salmonids were observed dead in the lake. The eliminated fish populations did not reappear by Sept. 1954. Fishing yield of salmonids increased from about 0.8 kg/ha to 2.0 kg/ha in 1954, primarily through the catch of larger fish. **REFERENCES**: Hayes and Livingstone (1955).

LAKE NAME: Corbett Lake
LOCATION: British Columbia, Canada
SURFACE AREA: 24.2 ha
MAXIMUM DEPTH: 19.5 m

PROBLEM: Insufficient autumnal overturn; low oxygen content prior to ice cover. Oxygen depletion during the winter resulting in salmonid mortality in six out of 10 years prior to 1962. **RESTORATION OBJECTIVE**: To increase the dissolved oxygen levels during autumnal overturn. **RESTORATION METHODOLOGY**: An aeration/circulation system was installed in late fall, 1962. It consisted of a 750 l/sec air compressor connected to 726 m of perforated tubing placed in a loop in the deepest part of the lake. The system was intermittently operated during October and November, 1962 and again in 1963. The rental cost of the compressor was $325 USA/month, and the tubing cost $400. In 1964 the line-release system was replaced with a single air diffuser. Air was supplied with a 17 l/sec compressor. Initially, the diffuser operated at the base of a 13 m long, 0.6 m diameter vertical tube which contained the rising bubbles, but the tube was not used in 1965 or in subsequent years. Total construction costs for the diffuser system were $774, excluding labor and design, and monthly operating costs were $135. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Prior to circulation in 1962, the lake was stratified at a depth of 10 m. At the end of the circulation period and just prior to freeze-up, the mean oxygen concentration was more than 8 mg/l. In the previous year the surface concentration of dissolved oxygen was less than 4 mg/l prior to freeze-up and oxygen was absent below 14 m. During 1963, aeration raised the mean oxygen concentration to about 6 mg/l prior to freeze-up. Using either system, the mean dissolved oxygen content of the lake was increased sufficiently to prevent the development of critical levels during winter, although the rate of demand was comparable to previous years. **REFERENCES**: Halsey (pers. comm.), Halsey (1968), Halsey and Galbraith (1971).

LAKE NAME: Lake Erie
LOCATION: Canada and USA
SURFACE AREA: 26,000 km^2
MAXIMUM DEPTH: 64 m

PROBLEM: Eutrophication due to excessive nutrient loading–nuisance algal growth, oxygen depletion, and sedimentation. Some near-shore areas are especially polluted from industrial, municipal and urban runoff sources. **RESTORATION OBJECTIVE**: To improve the water quality to meet criteria for all uses. **RESTORATION METHODOLOGY**: An effort is underway to eliminate industrial discharges, abate combined sewer overflows, and improve municipal wastewater treatments. Municipal sewage treatment plants must remove 80% of the influent phosphorus by 31 December, 1975. The phosphorus in detergents was reduced to 20% (dry weight as P_2O_5) by 1 August, 1970 and to 5% by December, 1972. The total phosphorus loading in 1976 is to be one-half the loading of 1971 (the hydraulic residence time is about three years). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: An environmental assessment project is nearing completion. Through this project, a high level of understanding is being achieved on the present near-shore aquatic system. This information will be used to assess the impact of presently planned water pollution control projects and to modify them, or implement new projects where necessary. Treatability studies are completed or underway at municipal waste treatment plants. Detergent formulations were changed in accordance with regulations. The resulting lake conditions will be followed closely in future years. **REFERENCES**: Burns (pers. comm.), Burns and Ross (1972), Case (pers. comm.), Dobson (pers. comm.), Governments of Canada and the United States of America (1972), Haimes and Prober (pers. comm.), Higgins (pers. comm.), International Joint Commission, Canada and the United States (1970), Prober et al. (undated), Limnos (1972).

LAKE NAME: Fanshawe Lake
LOCATION: near London, Ontario, Canada
SURFACE AREA: 2.6 km^2
MAXIMUM DEPTH: 12.2 m

PROBLEM: Gradual enrichment by nutrients from the drainage basin resulting in deterioration of water quality for recreation and water supply. **RESTORATION OBJECTIVE**: To determine if the manipulation of the depth of discharge can be used effectively against the problems of eutrophication, especially in terms of dissolved oxygen. **RESTORATION METHODOLOGY**: During the summer of 1963 (11 June to 14 November) a bottom water discharge system was operated in the lake. Limnological data was available for comparison from the preceding 10 years of surface water discharge. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Before 1963, 15% ($1.85 \times 10^6 m^3$) and 45% ($5.55 \times 10^6 m^3$) by volume of the lake became deoxygenated and was less than 50% saturated with oxygen, respectively during the summer. Thermal stratification normally persisted from June through August. During 1963 the temperature gradient was slight due to a rise in bottom temperature and there apparently was some exchange between surface and bottom waters. About 1% ($1.23 \times 10^5 m^3$) and 20% ($2.47 \times 10^6 m^3$) by volume of the lake became deoxygenated and was less than 50% saturated with oxygen, respectively. The warm, nutrient-rich inflow probably mixed with the surface waters. Although variable, the discharge averaged about $1.48 \times 10^5 m^3$/day between 11 June and 28 August. **REFERENCES**: Johnson and Berst (1965).

LAKE NAME: Lake Huron
LOCATION: Canada and USA
SURFACE AREA: 60,000 km^2
MAXIMUM DEPTH: 230 m

PROBLEM: Degradation from industrial and municipal sources. **RESTORATION OBJECTIVE**: To maintain the water quality of the offshore waters (presently oligotrophic/mesotrophic) and to reduce the degradation occurring in localized areas. **RESTORATION METHODOLOGY**: Several abatement measures are under consideration/implementation. Studies are now being conducted to identify the pollution sources, document the present condition of the lake and the effect of the various pollutants, and determine the permissible phosphorus loading. The Saginaw Bay area is of particular interest due to severe pollution. The several agencies involved include the United States Geological Survey, Environmental Protection Agency, Canadian Center for Inland Waters, Ontario Water Resources Commission, National Oceanic and Atmospheric Administration and the Department of Natural Resources of adjacent states. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment results are not yet available. Models are being formulated to forecast the water quality as affected by natural and man-made conditions. **REFERENCES**: Cline (pers. comm.), Dobson (pers. comm.), Governments of Canada and the United States (1972), Shrivastava (pers. comm.), Limnos (1972).

LAKE NAME: Kootenay Lake
LOCATION: south-central British Columbia, Canada
SURFACE AREA: 415 km^2
MAXIMUM DEPTH: 154 m

PROBLEM: Periodically heavy summer algal blooms and excessive epibenthic algal and macrophyte growth along the shoreline. **RESTORATION OBJECTIVE**: To prevent or restrict the excessive growth of algae and macrophytes. **RESTORATION METHODOLOGY**: The loading of phosphorus from a phosphate fertilizer plant on the major inlet was reduced by improved impoundment facilities. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There was an appreciable decrease in phosphate loading to the lake following installation of the improved impoundment facilities; further monitoring of nutrients and algae is continuing. **REFERENCES**: Northcote (pers. comm.), Northcote (in press a and b), Northcote (1972).

LAKE NAME: Mildred Lake

LOCATION: Jasper National Park, Alberta, Canada
SURFACE AREA: 3.2 ha
MAXIMUM DEPTH: 3.7 m

PROBLEM: Influx of laundry wastes. Overabundance of macrophytes and algae, resulting from the use of phosphate detergents; fish unable to survive. **RESTORATION OBJECTIVE:** To control algae and macrophytes with chemicals and to maintain winter oxygen levels through aeration. **RESTORATION METHODOLOGY:** Chem-Pels 2-4 D formulation was used for macrophyte control while Phygon X-L and copper sulfate were used to kill algal growths. Aeration began as soon as ice formed and continued all winter. Salmonids were stocked to see if survival could be brought about over the winter. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Macrophyte growth was reduced for the first year only. Algal production was curtailed temporarily but a prolonged spell of calm, sunny weather soon brought it back in dense mats along the shores. Air bubbling maintained adequate oxygen until late January when cold, windy weather almost closed the open water areas. The fish died within a week. The lake has now been abandoned to its fate since it has not been possible to have the laundry wastewaters drained elsewhere. **REFERENCES:** Ward (pers. comm.).

LAKE NAME: Millers Lake

LOCATION: Alberta, Canada
SURFACE AREA: 29 ha
MAXIMUM DEPTH: 7 m

PROBLEM: Winterkills; dissolved oxygen depletion due to the die-off of extensive aquatic vegetation. **RESTORATION OBJECTIVE:** To maintain dissolved oxygen at adequate levels for fish survival. **RESTORATION METHODOLOGY:** A compressor-diffuser system was used to aerate the lake during the winter and to maintain an open water area. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The aeration system was only marginally successful. About 0.6 ha of open water was maintained, but during a winter with heavy snowfall and white ice formation, a partial fishkill occurred. **REFERENCES:** Hawryluk (pers. comm.).

LAKE NAME: Okahagan Lake

LOCATION: south-central British Columbia, Canada
SURFACE AREA: 340 km^2
MAXIMUM DEPTH: 244 m

PROBLEM: Localized dense macrophyte growth resulting from stream siltation (by erosion) and municipal nutrient loading. Several large public recreation areas have been impaired. **RESTORATION OBJECTIVE:** To curtail the nutrient loading and siltation to levels which will not support aquatic growth; and to reclaim the infested recreation areas. **RESTORATION METHODOLOGY:** The municipal sewage effluent was treated by spray irrigation. Erosion control measures were initiated for the stream banks. Macrophytes were harvested mechanically (about 410,000 kg in 1972). **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The project is too new to observe permanent results; however, mechanical harvesting of aquatic weeds did not provide for recreational use of the water which would not have otherwise been possible. **REFERENCES:** Parchomchuk (pers. comm.).

LAKE NAME: Lake Ontario

LOCATION: Canada and USA
SURFACE AREA: 19,500 km^2
MAXIMUM DEPTH: 244 m

PROBLEM: Advanced cultural eutrophication. Degradation from industrial and municipal sources. Nuisance algal growth, oxygen depletion, deteriorating fishery, and siltation. **RESTORATION OBJECTIVE:** To restore the water quality to a standard tolerable for multi-purpose recreation, water supply, and fish production. **RESTORATION METHODOLOGY:** A variety of abatement measures are being implemented or are under consideration. Sewage treatment plants will remove phosphorus (80%) from influent wastes by 31 December, 1975. The phosphorus in detergents was reduced to 20% (dry weight as P_2O_5) by 1 August, 1970 and to 5% by December 1972. In certain areas additional techniques include land use controls and construction of interceptor sewers. The total phosphorus loading in 1976 is to be one-half the loading of 1971. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Baseline data are now being collected by several agencies for the assessment of treatment effects (biotic and abiotic). Lake conditions will be observed closely in future years. Identification and quantification of pollutant sources are still underway. **REFERENCES:** Baldwin and Sweeney (1973), Dobson (pers. comm.), Downing et al. (1973), Dworsky (pers. comm.), Forest (pers. comm.), Governments of Canada and the United States of America (1972), Higgins (pers. comm.), Hurley (pers. comm.) International Joint Commission, Canada and the United States (1970), Johnson (pers. comm.), Proto and Sweeney (1973), Zimmerman (pers. comm.).

LAKE NAME: Pinks Lake

LOCATION: Gatineau Park, Quebec, Canada
SURFACE AREA: 12.1 ha
MAXIMUM DEPTH: 32 m

PROBLEM: Biogenic meromictic lake. Intensification of algal blooms in recent years; minimum Secchi disk now less than 2 m. *Microcystis, Chroococcus, Synedra,* and *Dinobryon* are the problem species. **RESTORATION OBJECTIVE:** To eliminate the algal blooms and slow the rate of eutrophication. **RESTORATION METHODOLOGY:** The study began in 1972 and is still in a pre-treatment stage. A restoration technique has not yet been selected; a nutrient limitation procedure will probably follow the present study. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** A nutrient budget is being compiled and in-lake studies include nutrients, phytoplankton, dissolved oxygen, sedimentation rate, and sediments. **REFERENCES:** Dickman (pers. comm.).

LAKE NAME: Lake Ramsey

LOCATION: Sudbury, Ontario, Canada
SURFACE AREA: 8.2 km^2
MAXIMUM DEPTH: 19.8 m

PROBLEM: Taste and odor problems due to algal growths. The lake is used as a municipal water supply. **RESTORATION OBJECTIVE:** To eliminate the taste and odor problems by reducing algal abundance. **RESTORATION METHODOLOGY:** In early November $CuSO_4$ was applied at a rate of 22.4 kg/ha to the littoral zone and 56 kg/ha to the pelagic area. About one month later 33.7 kg/ha was applied over most of the lake. Application was by aircraft. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** After the initial treatment, the algal count dropped from 33,400 areal standard units to 2,500 and the odor number dropped from 200 to 24. Within two weeks the algal count rebounded to 5,000 and the odor number, to 140; the copper concentration remained the same during this period. One week after the second treatment–following ice cover–the lake's algal count was back down to 2,000 and the odor number to 17. By the end of December, the water was satisfactory for municipal use with only slight noticeable odor (algae count 1,300; odor number 4). **REFERENCES**: Bronse (1966).

LAKE NAME: Lake Rose
LOCATION: Nicolet County, Quebec, Canada
SURFACE AREA: 46.6 ha
MAXIMUM DEPTH: 2.7 m

PROBLEM: Eutrophic conditions induced by agricultural and domestic wastes. Macrophytes and algal blooms; fishkills. Bacterial pollution. **RESTORATION OBJECTIVE**: To limit the vegetation growth and to reduce the bacterial pollution. **RESTORATION METHODOLOGY**: The macrophytes *(Elodea canadensis)* will be harvested annually and the influx of wastes from the cottages will be stopped. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The first harvesting was conducted during the last summer. A main sewer is being constructed to collect the cottage wastes. Results are not yet available. **REFERENCES**: Bernard (pers. comm.), Bernard and Rochon (1971).

LAKE NAME: Lake Saint-Joseph
LOCATION: Portneuf County, Quebec, Canada
SURFACE AREA: 11 km^2
MAXIMUM DEPTH: 38 m

PROBLEM: Sewage disposition; influx of wastes from cottages. **RESTORATION OBJECTIVE**: To stop the sewage influx and prevent further eutrophication of the lake. There is no particular problem as yet. **RESTORATION METHODOLOGY**: A main sewer is being constructed around a part of the lake and should be completed by spring, 1974. Septic system installations are being regulated around the rest of the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Limnological studies will continue after treatment. The hydraulic residence time is 125 days. It was not possible to estimate the nutrient loadings to the lake. **REFERENCES**: Bernard (pers. comm.), Rochon (pers. comm.), (1971).

LAKE NAME: Skaha Lake
LOCATION: Okanagan Valley, British Columbia, Canada
SURFACE AREA: 20.7 km^2
MAXIMUM DEPTH: 57 m (mean depth, 26 m)

PROBLEM: Excessive macrophytes and nuisance blue-green algal blooms. Sewage plant effluent causing eutrophication. **RESTORATION OBJECTIVE**: To install advanced wastewater treatment for phosphate removal with a goal of 80% reduction in the P content. **RESTORATION METHODOLOGY**: The treatment process was modified to include tertiary treatment with lime precipitate at a cost of $280,000-300,000 USA. Improved operation essentially began in 1972; P removal is still only 60% but with experience should increase to 80%. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Nutrient loadings have been measured; before treatment about 1.02 g P/m^2/yr and now 0.64 g P/m^2/yr (nitrogen–8.15 g/m^2/yr). The hydraulic residence time is 1.2 yrs. A variety of physico-chemical and biological parameters are being monitored; analyses include attention to water quality modeling. Post-treatment results not yet available. **REFERENCES**: Stockner (pers. comm.; several reports/doctoral thesis are in preparation).

LAKE NAME: Lake Superior
LOCATION: Canada and USA
SURFACE AREA: 82,000 km^2
MAXIMUM DEPTH: 400 m

PROBLEM: Degradation from industrial and municipal sources; deposition of particulate mining waste. **RESTORATION OBJECTIVE**: To maintain the oligotrophic status of the offshore waters and to reduce the degradation occurring in the western portion of the lake. **RESTORATION METHODOLOGY**: The major population center in the western portion of the lake will have secondary treatment facilities by 1973. Storm overflows should be eliminated by 1979; technique has not yet been chosen. Other abatement measures are under consideration. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Studies are now being conducted to document the present condition of the lake and the effect of the various pollutants and to determine the permissible phosphorus loading. Data acquisition has not been completed. **REFERENCES**: Dobson (pers. comm.), Governments of Canada and the United States of America (1972), Swain (pers. comm.), Limnos (1972).

LAKE NAME: Thompson Lake
LOCATION: Toronto, Ontario, Canada
SURFACE AREA: 4 ha
MAXIMUM DEPTH: 26 m

PROBLEM: Highly enriched due to intensive agricultural practices within the basin. In the summer, the anaerobic hypolimnion extends to within 3 m of the lake's surface resulting in a limited fish habitat. **RESTORATION OBJECTIVE**: To maintain oxygen in the lake at all depths in order to develop a salmonid fishery. **RESTORATION METHODOLOGY**: An air diffuser was placed on the lake bottom at the 21 m depth to destratify the lake. Air was supplied with a compressor rated at 4.7 l/sec. Capital cost of the aeration system was $800 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The system was started on 22 November, 1972. Water chemistry and algal response are being monitored, but results are not available. **REFERENCES**: Brydges (pers. comm.).

LAKE NAME: Lake Wabanum
LOCATION: Parkland County, Alberta, Canada
SURFACE AREA: 81 km^2
MAXIMUM DEPTH: 6.1–9.2 m

PROBLEM: Submergent vegetation interfering with maximum utilization of lake for recreational purposes. Infested area of about 1.2 km^2. **RESTORATION OBJECTIVE**: To manage the plant growth in a manner that will maximize lake utilization without environmental disturbance. **RESTORATION METHODOLOGY**: Macrophytes are harvested mechanically; research is being conducted into the relative effectiveness of various herbicides and application rates. The effect of thermal discharge on macrophyte growth rates and species distribution is also under study. The cost of harvesting in 1972 was $90,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The project is in the second year of a multiple-year program. Control of certain species with herbicides appears promising. The harvesting operation maintained open waters satisfactory to lake users. A program is now underway to reduce the thermal pollution of the lake. **REFERENCES**: Allan and Yarish (1972), Masuda and Briggs (pers. comm.), Yarish (pers comm.), Yarish and Allan (1971).

LAKE NAME: Welland Canal
LOCATION: Ontario, Canada
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Possible deterioration of water quality in the Welland Canal after its closing. The existing canal will be replaced with a new one in 1973; nuisance algal blooms are anticipated after the canal closing. **RESTORATION OBJECTIVE**: To develop procedures for protecting the water quality. To determine the efficacy and feasibility of alum treatment as compared to other control alternatives. **RESTORATION METHODOLOGY**: Three techniques were studied: (1) treatment with aluminum sulfate at a dosage of 5 mg/l as Al, (2) maintenance of a four day hydraulic residence time, and (3) application of copper sulfate at a rate of 1 mg/l. Alum treatment cost about $290 USA/ha. The tests were conducted in three separate basins of a previously used canal. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Algal productivity was limited by each of the techniques; alum treatment was more effective than the four day retention time. Copper sulfate application reduced the productivity for 2-3 weeks only. Initially the alum reduced the total phosphorus concentrations to 10 μg/l; in addition, turbidity decreased and water transparency increased. However, by the end of summer pre-treatment conditions again existed due to the shallowness of the basin and the influx of suspended materials in the runoff waters. More permanent results would be expected from treatment of the soon-to-be-closed canal because of the deeper basin. The investigation is continuing, including analyses of various biological data. **REFERENCES**: Shannon and Vachon (1973).

LAKE NAME: Winnipeg water supply reservoirs
LOCATION: Winnipeg, Manitoba, Canada
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Taste and odors associated with seasonal algal growths. **RESTORATION OBJECTIVE**: To decrease algal growth problems in storage reservoirs by treatment of inflow. **RESTORATION METHODOLOGY**: Four areas were used for the testing of aluminum (5 mg alum/l), copper, and filtration for algal removal and/or growth reduction. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Microstraining was less effective than multi-media filters for the removal of algae and amorphous matter. Copper and Al (III) treatment reduced inorganic phosphorus concentrations and algal growth. Other studies with Al (III) alone were inconclusive. **REFERENCES**: Klassen et al. (1970).

LAKE NAME: Yellow Lake
LOCATION: Kaledon, British Columbia, Canada
SURFACE AREA: 40 ha
MAXIMUM DEPTH: 37 m

PROBLEM: Low dissolved oxygen conditions during the winter. Available data indicated that incomplete autumnal circulation may have been responsible for the winter oxygen depletions. **RESTORATION OBJECTIVE**: To provide favorable winter dissolved oxygen conditions for salmonids by completely circulating the lake during the fall and building up the store of available oxygen. **RESTORATION METHODOLOGY**: Three 2 m diameter cross-shaped air diffusers were suspended over the deepest parts of the lake at the 15 m level. Air was supplied by a shore-based diesel powered compressor rated at 75 l/sec. For two months of operation during November and December, 1969, the total cost of aeration was about $1800 USA, exclusive of labor but including compressor rental and capital cost of equipment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Due to the circulation of bottom water with a high oxygen demand and high levels of hydrogen sulfide, continuous operation caused the surface dissolved oxygen concentrations to drop below 3 mg/l, resulting in fishkills. After raising the diffusers from 15 m to 3 m the surface concentrations increased satisfactorily. Overwinter fish survival was good and a successful fishery occurred the following year. A late winter thaw also had a favorable effect on the dissolved oxygen levels. **REFERENCES**: Halsey (pers. comm.), Halsey and MacDonald (1971).

LAKE NAME: Irrigation canals
LOCATION: E of Kosice, Czechoslovakia
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of macrophytes–emergents and submergents. **RESTORATION OBJECTIVE**: To reduce the macrophyte densities to subnuisance levels. **RESTORATION METHODOLOGY**: Grass carp *(Ctenopharyngodon idellus)* were introduced to control the macrophytes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The canals with grass carp have been observed to be vegetation-free; however, in those without carp, several types of vegetation (e.g., *Solvenia, Scirpus, Phragmites, Lamina,* and *Cladaphora*) grow abundantly. **REFERENCES**: Sladecek (pers. comm.).

LAKE NAME: Lubi Reservoir
LOCATION: Trebic, Czechoslovakia
SURFACE AREA: 3.3–4.3 ha
MAXIMUM DEPTH: 7 m

PROBLEM: Nuisance bloom of *Aphanizomenon flos-aquae* in early July, 1963; moderate blooms persisted through July, August and September. These high algal densities were apparently caused by enriched water entering the upper end of the reservoir. **RESTORATION OBJECTIVE**: To prevent the mass development of an algal bloom, and the resulting water quality deterioration, with application of the algicide CA 350. **RESTORATION METHODOLOGY**: Copper sulfate (72 kg) was applied using the tow-bag method (two bags were towed on each side of a boat). Silver nitrate (4.8 kg) was applied from a sprayer as a uniform mist falling on the water surface. Water samples were taken for analysis from several locations, both horizontally and vertically, shortly before the treatment was performed, 15-18 hours following the action, and then at weekly intervals. During the time of treatment, biological, physical and some chemical analyses were also made directly in the field. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The algicide CA 350 was found to act immediately against blue-green algae without any side effects produced by the copper. The first of two applications was made in May, 1964, in order to remove a blue-green algal bloom. The blue-green algae disappeared within 24 hours of the treatment with no marked changes in other biological and chemical characteristics of the reservoir water. Two weeks later heavy development of green algae was noted but it ceased after a short interval and had no bad effects on the raw water quality. About six weeks following the application, *Hydrodictyon reticulatum,* a green algae, developed in the lower part of the reservoir. The second application was not discussed in detail; the results were reportedly similar to the first application. **REFERENCES**: Kocurova (1966).

LAKE NAME: Bagsvaerd Sø
LOCATION: about 11 km NNW of Copenhagen, North Zealand, Denmark
SURFACE AREA: 1.2 km^2
MAXIMUM DEPTH: 4.5 m

PROBLEM: Sewage from 12,000 people entering the lake. A pronounced increase in the rate of eutrophication was taking place. **RESTORATION OBJECTIVE**: To decrease or reverse the rate of lake eutrophication through sewage diversion. **RESTORATION METHODOLOGY**: Nearly all of the sewage was diverted in July, 1959. The treatment plant effluent now enters a small river flowing to the ocean. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After diversion–studied in 1962, 1968, and 1969–low values of water clarity and high rates of primary production continued within the lake. However, the maximum gross production per volume of lake water was reduced greatly. The highest pre-diversion value was 20-21 x 10^3 mg C/m^3/day in July, 1959; subsequently, the highest value occurred in August, 1969 at 10-11 x 10^3 mg C/m^3/day. The greatest reduction was noted between 1959 and 1962, with erratic fluctuation thereafter. **REFERENCES**: Johnson et al. (1962), Mathiesen (1971).

LAKE NAME: Lyngby Sø
LOCATION: North Zealand, Denmark
SURFACE AREA: 59 ha
MAXIMUM DEPTH: 2.8 m

PROBLEM: Purified sewage from 13,600 people discharging into the lake. A pronounced increase in the rate of eutrophication took place before 1959. **RESTORATION OBJECTIVE**: To decrease or reverse the rate of lake eutrophication through sewage diversion. **RESTORATION METHODOLOGY**: Nearly all of the sewage was diverted in February, 1959. The treatment plant effluent now enters a small river flowing to the ocean. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The water replacement rate was 2-3 months. Gross primary production decreased from 775 mg C/m^2 of lake surface in 1959 to 330 mg C/m^2 in 1962 with the greatest drop occurring between 1959 and 1960. An increase in water clarity and decrease in maximum gross production per volume of lake were also recorded during this period. During 1962-69 the nutrient influx increased from other sources in the watershed. The loading levels increased from 7400 kg N/yr and 500 kg P/yr in 1961 to 12,000 kg P/yr by 1967. Primary production increased as a result of the higher loadings. **REFERENCES**: Johnson et al. (1962), Mathiesen (1971).

LAKE NAME: Pedersborg Sø
LOCATION: Central Zealand, Denmark
SURFACE AREA: 19 ha
MAXIMUM DEPTH: 3.5 m

PROBLEM: Advancing eutrophication; influx of large quantities of purified sewage. **RESTORATION OBJECTIVE**: To divert the sewage effluent out of the lake system. **RESTORATION METHODOLOGY**: The major part of the sewage effluent was diverted from the lake during 1967. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Measurements taken in 1959-60 were compared with those from 1967. There was a marked decline in gross primary production after diversion; in 1959-60 the maximum was about 16 x 10^3 mg C/m^3/day in mid-summer but the highest value in 1969 was 4-5 x 10^3 mg C/m^3/day. However, many limnological measurements still indicated a heavily polluted lake with an oxygen deficit and hydrogen sulfide present in the bottom waters. **REFERENCES**: Johnson et al. (1962), Mathiesen (1971).

LAKE NAME: Uttersler Mose
LOCATION: near Copenhagen, North Zealand, Denmark
SURFACE AREA: 1 km^2
MAXIMUM DEPTH: --- (mean depth, 1 m)

PROBLEM: Influx of domestic wastes from an overloaded trickling filter (sewage treatment plant); obnoxious odors emanate from the lake. There is little inflow from surface runoff. **RESTORATION OBJECTIVE**: To eliminate the eutrophication-related problems. **RESTORATION METHODOLOGY**: The sewage effluent was diverted in the late 1960's; treatment with aluminum sulfate occurred soon afterward. An experimental treatment plant was built capable of handling about 100 m^3/hr. Lake water was pumped into the plant and alum added. The flow was regulated by observing floc formation and subsequent sedimentation; the desired concentration was 100 mg/l of alum (9% Al). About once a week operation stopped while the settling basins were cleaned. The total lake volume could be treated in 120 days. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There was good phosphate removal–soluble and suspended. Soluble phosphate was reduced to the point where further treatment was unjustified. Treatment was effective in reducing concentrations in the lake for about one year. Much phosphate may originate from sludge on the lake bottom. **REFERENCES**: Canada Centre for Inland Waters (unpublished report), Malueg (pers. comm.; letters from R. B. Dean).

LAKE NAME: Arendsee
LOCATION: Altmark, East Germany
SURFACE AREA: 5 km^2
MAXIMUM DEPTH: 49.5 m (mean depth, 29.5 m)

PROBLEM: Decreasing DO levels in hypolimnion; PO_4 being liberated from sediment causing internal fertilization; nuisance algal blooms; and general eutrophication. **RESTORATION OBJECTIVE**: To preserve the value of the lake as a fishery and recreational area (currently high recreational use). **RESTORATION METHODOLOGY**: A ring canal is currently under construction. Sewage will be collected, treated, and released downstream from the lake. The estimated cost of the diversion is about $1,100,000 USA. A hypolimnetic discharge is also planned at an estimated cost of $125,000. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Water quality has not noticably improved despite partial implementation of the collection, treatment, and diversion system, probably because of the rather long hydraulic residence time of the lake. The planned hypolimnetic diversion is expected to speed up improvement in P- and N-conditions. **REFERENCES**: Klapper (pers. comm.; publications are in preparation).

LAKE NAME: Saidenbach Reservoir
LOCATION: Erzgebirge, East Germany
SURFACE AREA: 1.5 km^2
MAXIMUM DEPTH: 45 m

PROBLEM: Algal blooms (diatoms) influencing drinking water use. Eutrophic conditions are caused by the intensive agriculture in the drainage area. **RESTORATION OBJECTIVE**: To limit growth of planktonic algae and to improve dissolved oxygen conditions by reducing the phosphorus concentration in the inflows. **RESTORATION METHODOLOGY**: For all inflows, pre-impoundment basins have been designed to function as "algal reaction basins." The dissolved phosphate compounds will be incorporated into the algal biomass and a great deal of the algae removed by natural flocculation and sedimentation. The optimum detention time of the pre-impoundment basin was calculated by means of a simple mathematical model. The investment costs are relatively high but the operating costs are very low. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Laboratory models and pre-impoundment basins of other reservoirs demonstrate a phosphate removal of about 50% of the inflow concentration. **REFERENCES**: Benndorf (in press), Beuschold (1966), Uhlmann et al. (1971), Uhlmann, Benndorf, and Höhne (pers. comm.).

LAKE NAME: Äyhönjärvi
LOCATION: Rauma, Finland
SURFACE AREA: 25 ha
MAXIMUM DEPTH: 2 m

PROBLEM: Reduced water storage capacity and poor water quality due to sedimentation. The lake is used for municipal water supply. **RESTORATION OBJECTIVE**: To deepen the lake in order to increase the storage capacity and improve the recreational value. **RESTORATION METHODOLOGY**: In 1972 a hydraulic dredge removed 300,000 m^3 of sediments at a cost of $175,000 USA or $0.58/m^3$. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Water storage capacity has been increased and the quality of the water has improved. **REFERENCES**: Isotalo (pers. comm.).

LAKE NAME: Dämman
LOCATION: Espoo, Finland
SURFACE AREA: 11 ha
MAXIMUM DEPTH: 8 m

PROBLEM: Excessive algal growths; DO depletion during summer (bottom waters) and winter; problem concentrations of manganese in the hypolimnion. Used as a water supply reservoir. **RESTORATION OBJECTIVE**: To improve the chemical conditions and to prevent oxygen depletion by hypolimnetic discharge of waters. **RESTORATION METHODOLOGY**: Three plastic pipes were placed into the artificial lake. A 200 mm diameter pipe was installed to a depth of 6 m and two 30 mm diameter pipes, to depths of 7-8 m. These were extended downstream from the dam and operated continuously by siphon action; 20 l/sec was discharged from the 200 mm pipe. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The installation began operating the summer of 1968. Significant changes were noted within one month. Thermal stratification was greatly reduced; DO depletion was prevented, and the water quality was improved near the bottom. During the subsequent winter, the system resulted in increased DO and reduced temperatures in the bottom waters. No detrimental effects of system operation were observed within the lake. Odor and a high iron and manganese content were problems in the downstream channel. **REFERENCES**: Hämäläinen (1969).

LAKE NAME: Evijärvi
LOCATION: west central Finland
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Excessive growths of *Scirpus, Phragmites, Equisettum*, and *Spaeghonium*, especially in a 1.4 km^2 bay (Kniivilä). The area is 2/3 rds covered with vegetation. **RESTORATION OBJECTIVE**: To remove nutrients and macrophytes by mechanical harvesting of the vegetation. **RESTORATION METHODOLOGY**: The harvesting and collection equipment was constructed and put into operation in 1973. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. The equipment functions well; and preliminary estimates indicate that removal of all of the macrophytes (1 mg P/l; dry weight) will eliminate 600 kg P from the lake. **REFERENCES**: Seppänen (pers. comm.).

LAKE NAME: Gallträsk
LOCATION: northwest of Helsinki, Finland
SURFACE AREA: 12 ha
MAXIMUM DEPTH: 1.3 m

PROBLEM: Excessive macrophytes; DO depletion; fishkills. Influx of municipal wastewaters. This lake flows into Lippajärvi. **RESTORATION OBJECTIVE**: To restore the recreational and aesthetic values of the lake. **RESTORATION METHODOLOGY**: The wastewaters are now being diverted from the lake. In the future the water level will be lowered for one to two years followed by excavation-in-the-dry. The lake will be deepened by 1 m, including removal of the upper 10 cm of nutrient-rich, organic sludge. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Comprehensive background information has been and is being compiled on the sediments and interstitial waters (e.g., paleolimnology and Algal Growth Potential). Treatment will probably be implemented in 1974. **REFERENCES**: Alhonen (1972), Seppänen (pers. comm.).

LAKE NAME: Harinjärvi
LOCATION: east central Finland
SURFACE AREA: 81 ha
MAXIMUM DEPTH: 40 m

PROBLEM: Nuisance algal blooms. Influx of sewage from a military base of about 500 people. **RESTORATION OBJECTIVE**: To alleviate the algal problem and protect the recreational values of the lake. **RESTORATION METHODOLOGY**: The biologically treated sewage was diverted to a land disposal site in 1957. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Lake conditions were greatly improved, including: (1) increased water clarity (Secchi disk), (2) higher DO content, (3) greater diversity of the plankton population, and (4) disappearance of certain algal species indicative of eutrophication. The improved conditions have been maintained to date. **REFERENCES**: Seppänen (pers. comm.), Seppänen (1964).

LAKE NAME: Illoistenjärvi
LOCATION: Finland
SURFACE AREA: 8.8 ha
MAXIMUM DEPTH: 2.5 m

PROBLEM: High concentration of phosphorus in the surface layer of the bottom sediments; originates from the wastewater of a laundry. The lake has become eutrophic. **RESTORATION OBJECTIVE**: To make the lake suitable for recreation. **RESTORATION METHODOLOGY**: Plans are to dredge the surface layer of the bottom sediments or chemically precipitate phosphorus using aluminum sulfate. The vegetation will also be harvested mechanically. The nutrient influx from the laundry has stopped. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Isotalo (pers. comm.).

LAKE NAME: Kakskerranjärvi
LOCATION: Finland
SURFACE AREA: 1.7 km^2
MAXIMUM DEPTH: 15 m

PROBLEM: Hypolimnetic oxygen depletion resulting in high nutrient concentrations. **RESTORATION OBJECTIVE:** To remove the poor quality water. **RESTORATION METHODOLOGY:** There is a proposal to discharge poor quality water from the hypolimnion. A special tube will be installed in the bottom of the lake and extend into the downstream channel; it will operate by siphon action. The nutrient influx will also be limited by voluntary action of the lakeshore residents. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Results are not yet available; the project is still in a pre-implementation stage. **REFERENCES:** Isotalo (pers. comm.).

LAKE NAME: Kiteenjärvi
LOCATION: southeast Finland
SURFACE AREA: 12.8 km^2
MAXIMUM DEPTH: 12.8 m

PROBLEM: Oxygen depletion in the bottom waters during the winter. Various other eutrophication-related problems in this recreation/fishing lake. **RESTORATION OBJECTIVE:** To improve the conditions by aeration of the bottom waters. **RESTORATION METHODOLOGY:** Pilot testing of some type of aeration system will begin during winter, 1973. Hypolimnetic aeration only will probably be attempted because Algal Growth Potential testing indicates that algal production will be greatly increased if the bottom and surface waters are mixed. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Pre-treatment investigations are underway. Limnological information is available for about the last 10 years. **REFERENCES:** Seppänen (pers. comm.).

LAKE NAME: Lippajärvi
LOCATION: northwest of Helsinki, Finland
SURFACE AREA: 58 ha
MAXIMUM DEPTH: 4.5 m

PROBLEM: Nuisance algal blooms; generation of H_2S; poor hygienic conditions; low DO in the winter. Due to the past influx of sewage and the inflow of waters from a highly developed drainage basin. **RESTORATION OBJECTIVE:** To improve the aesthetic and recreational values of the lake. **RESTORATION METHODOLOGY:** Water was withdrawn from the hypolimnion starting in spring, 1972. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Investigations are in progress. **REFERENCES:** Seppänen (pers. comm.).

LAKE NAME: Mytajärvi
LOCATION: near Lahti, Finland
SURFACE AREA: 1.5 ha
MAXIMUM DEPTH: 10.5 m

PROBLEM: Nuisance algal blooms in summer. Eutrophication-related problems in general. **RESTORATION OBJECTIVE:** To halt and reverse the trend toward increased eutrophication. To improve the water conditions for aesthetics and swimming. **RESTORATION METHODOLOGY:** On 6 April, 1973 aluminum sulfate (3000 kg; 150 g/m^3) was spread dry on the ice and allowed to mix naturally with the lake waters after ice thaw. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Using *Ankistrodesmus falcatus*, before treatment the AGP (Algal Growth Potential) was 8 mg/l and 440,000 cells/ml. One month later, the weight was reduced by 50% and the number of cells, by 25%. The total phosphorus concentrations were 0.05 and 0.17 mg/l at 1 and 10 m, respectively before treatment. On 4 May, 1973 the levels were 0.03 mg/l at 1 m and 0.04 mg/l at 7 m. Nevertheless, because the phosphorus was not dropped below threshold levels, nuisance algal blooms were again observed by June. Additional work is in progress. **REFERENCES:** Seppänen (pers. comm.).

LAKE NAME: Pitkajärvi
LOCATION: southern Finland
SURFACE AREA: 1.7 km^2
MAXIMUM DEPTH: 6 m

PROBLEM: Massive algal blooms and winter DO depletion. Influx of wastewaters and nutrient-rich waters from the drainage basin. **RESTORATION OBJECTIVE:** To maintain dissolved oxygen levels suitable for fish survival. **RESTORATION METHODOLOGY:** An aeration/circulation system will be installed and begin operation in winter, 1974. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Treatment has not yet been implemented. **REFERENCES:** Seppänen (pers. comm.).

LAKE NAME: Ruokojärvi
LOCATION: southwest Finland
SURFACE AREA: 1 km^2
MAXIMUM DEPTH: 4.1 m

PROBLEM: Nuisance algal blooms in summer and near total depletion of DO in winter. **RESTORATION OBJECTIVE:** To restore the recreational potential of the lake and to protect the fishery. **RESTORATION METHODOLOGY:** Treatment is planned for late 1974, probably some method of aeration/circulation. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Investigations are in progress. **REFERENCES:** Seppänen (pers. comm.).

LAKE NAME: Särkinen
LOCATION: Finland
SURFACE AREA: 46 ha
MAXIMUM DEPTH: 16 m

PROBLEM: Nuisance algal blooms in summer and low DO in winter. Previous recipient of sewage. Important year-round recreational area. **RESTORATION OBJECTIVE:** To alleviate the problem conditions in order to protect and enhance the recreational values of the lake. **RESTORATION METHODOLOGY:** Treatment is tentatively planned for the winter of 1974-75, probably hypolimnetic aeration. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Pre-treatment investigations include an Algal Growth Potential testing program. **REFERENCES:** Seppänen (pers. comm.).

LAKE NAME: Taattistenjärvi
LOCATION: Finland
SURFACE AREA: 50 ha
MAXIMUM DEPTH: 6 m

PROBLEM: Nuisance algal blooms. Oxygen depletion. **RESTORATION OBJECTIVE:** To limit the planktonic algal growth and to improve oxygen conditions by reducing the phosphorus concentration. **RESTORATION METHODOLOGY:** The water is removed from the hypolimnion by pumping. In summer, 1972, $10^5 m^3$ of water was removed by pumping; the whole oxygen poor volume is $2 \times 10^5 m^3$. The expense including pump, tube, and electricity is $1750 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There was a decrease in the phosphorus concentration and an increase in the oxygen content within the hypolimnion. **REFERENCES**: Isotalo (pers. comm.).

LAKE NAME: Tuusulanjärvi
LOCATION: north of Helsinki, Finland
SURFACE AREA: 6.3 km^2
MAXIMUM DEPTH: 10 m

PROBLEM: Blue-green algal blooms and oxygen depletion during winter. Eutrophication caused mainly by agriculture and domestic wastewaters. **RESTORATION OBJECTIVE**: To eliminate the planktonic algal blooms and to improve the DO conditions for sport fish in order to enhance the lake's recreational value. **RESTORATION METHODOLOGY**: An aeration/circulation system was installed in the winter of 1969-70. Initially the equipment was used for small-scale testing; intensive aeration occurred during the winter of 1972-73. There is now a plan to discharge bottom waters from the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results of the aeration experiment are available and will be published in the near future. Investigations are continuing. **REFERENCES**: Keto and Seppänen (in press), Räty (pers. comm.), Seppänen (pers. comm.).

LAKE NAME: Vesijärvi
LOCATION: southern Finland
SURFACE AREA: 25.6 km^2
MAXIMUM DEPTH: 32 m

PROBLEM: Nuisance algal blooms; oxygen depletion below 10 m during summer and winter; excessive manganese concentrations. Influx of approx. 50 tons P/yr via domestic wastewaters. Used for water supply. **RESTORATION OBJECTIVE**: To improve the water quality for recreation and municipal supply. **RESTORATION METHODOLOGY**: The installation of a hypolimnetic aeration system is planned for the winter of 1974. Wastewater diversion will also begin within the next few years. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The project is in a pre-implementation stage. Substantial limnological data have been gathered beginning in 1925. **REFERENCES**: Seppänen (pers. comm.), Seppänen (1967).

LAKE NAME: Annecy
LOCATION: Alpine region, Haute Savoie near Annecy, France
SURFACE AREA: 27 km^2
MAXIMUM DEPTH: 64.7 m

PROBLEM: Eutrophication in progress since 1937 (oxygen depletion; algal blooms). The deterioration of water quality impairs the use as drinking water. **RESTORATION OBJECTIVE**: To decrease the nutrient input in order to obtain a water quality compatible with the uses of the lake (drinking water for about 100,000 inhabitants, tourism, and sport fisheries). **RESTORATION METHODOLOGY**: The lake is being surrounded with a ring canal to collect sewage from the small cities (industry is non-existent and agriculture consists mostly of extensive cattle breeding). The sewers are of the separative type. Cost (including the downstream purification plant) is about $14,000,000 USA. Construction began in 1961; half of the construction was finished by 1968 (44% of the population was connected). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The rate of water replacement is 3-1/3 years. By 1968 the trend toward increasing eutrophication had stopped in terms of water chemistry and algal populations. The quality of surface waters improved but the sediments bring back nutrients to the surface after oxygen depletion. Further action is required on the sediments. **REFERENCES**: Laurent and Balvay (pers. comm.; many publications are available), Laurent et al. (1970).

LAKE NAME: Bourget
LOCATION: Alpine region, Savoie near Chambery, France
SURFACE AREA: 44 km^2
MAXIMUM DEPTH: 145.4 m

PROBLEM: Oxygen depletion. Blooms of blue-green algae. Unpleasant smelling. Salmonid disappearance. Due to agriculture and urban development. **RESTORATION OBJECTIVE**: To stop the eutrophication occurring for the last 20 years. To limit the availability of phosphorus. **RESTORATION METHODOLOGY**: Sewage will be diverted outside the drainage basin (Rhone or Isere River). The sewers will not be separative and storm discharges will continue to flow into the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The lake is now strongly eutrophic. The protection planned will be achieved after 1975. Limnological studies are in progress. **REFERENCES**: Balvay (1968), Balvay and Laurent (1972), Hubault (1947), Laurent (1969), Laurent and Balvay (pers. comm.), Varet (pers. comm.).

LAKE NAME: Lake Leman (Geneva)
LOCATION: France and Switzerland
SURFACE AREA: 582 km^2
MAXIMUM DEPTH: 309 m

PROBLEM: Becoming eutrophic; increased phosphorus and other nutrients, resulting in occasional algal blooms. The lake is used for recreational purposes, fishing (Coregonids and Salmonids), and water supply. **RESTORATION OBJECTIVE**: To limit planktonic algal growth by reducing phosphorus concentrations; to improve water quality. **RESTORATION METHODOLOGY**: Domestic and industrial sewage treatment, including phosphorus elimination, is planned for the whole drainage basin. In 1968 about 44% of the population was connected to mechanical and biological treatment stations. The effluent enters the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: All projected treatment plants will be built by the end of 1975. At present, most of them are in operation. Water quality studies are being carried out. The water replacement rate is about 11-1/4 yr. No improvement in algal populations or water chemistry were observed during 1968. **REFERENCES**: Laurent et al. (1970), Pelletier (pers. comm.), Vernet et al. (1971).

LAKE NAME: Morillon
LOCATION: Thonon-les-Baines (Hte Savoie), France
SURFACE AREA: 4000 m^2
MAXIMUM DEPTH: 5.3 m

PROBLEM: Very high PO_4 and H_2S concentration in the hypolimnetic water; acute fishkill by oxygen depletion; actual natural mixotrophic conditions induced by previous urban sewages. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen conditions; to improve the physico-chemical composition of the sediments without physical removal; and to directly precipitate and inactivate the nutrients in the water. **RESTORATION METHODOLOGY**: Treatment will consist of superficial sediment resuspension and simultaneous addition of oxydant reactives. Precipitation, sorption, and settling from the water will occur via treatment with alum and kaolin. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Field and laboratory studies are attempting to determine the optimum application rates and procedures for different products. Application is planned for April, 1973. Limnological investigations are in process. **REFERENCES**: Barroin (pers. comm.).

LAKE NAME: Nantua
LOCATION: Ain, France
SURFACE ARES: 1.4 km^2
MAXIMUM DEPTH: 42 m

PROBLEM: Nuisance blue-green algal blooms, especially *Oscillatoria rubescens*. Disappearance of the coregonid fish. Acute eutrophic conditions apparently induced by domestic sewage. **RESTORATION OBJECTIVE**: To limit planktonic algal growth and to change the species occurring in the lake. To improve dissolved oxygen conditions near the bottom. **RESTORATION METHODOLOGY**: First, the sewage will be diverted to the outlet of the lake. Secondly, two projects are under consideration: 1) the "Limno" system (artifical aeration) and 2) a new original method using a partial dam. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: All sewages will be diverted in April, 1973. Physico-chemical and biological studies are in progress. The hydraulic residence time is 2/3 year. **REFERENCES**: Feuillade (pers. comm.; several publications are available), Laurent et al. (1970).

LAKE NAME: Paladru
LOCATION: Isere, France
SURFACE AREA: 3.9 km^2
MAXIMUM DEPTH: 36 m

PROBLEM: Disappearance of salmonids due to a serious oxygen deficit. Development of nuisance blooms of *Oscillatoria rubescens*. **RESTORATION OBJECTIVE**: To stop the process of eutrophication. **RESTORATION METHODOLOGY**: Treatment will include removal of some of the inhabitants who now border the watercourse, protection of a major part of the drainage basin, and diversion of wastewaters into the watercourse below the lake. Also, the deoxygenated water will be siphoned from the bottom of the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Pre-treatment studies are underway. **REFERENCES**: Lascombe (pers. comm.; reports are available).

LAKE NAME: Mar of Parentis
LOCATION: southwest France
SURFACE AREA: 50 km^2
MAXIMUM DEPTH: 25 m

PROBLEM: Periodic algal blooms of *Cyanophycea* altering the taste and odor of the water and producing an oxygen deficit near the bottom of the lake. **RESTORATION OBJECTIVE**: To limit the blue-green algal growth and to improve the dissolved oxygen conditions. **RESTORATION METHODOLOGY**: The lake is under study; treatment plans have not been formalized. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Balland (pers. comm.).

LAKE NAME: Barrage du Pas du Riot
LOCATION: Rochetaillee, France
SURFACE AREA: 10 ha
MAXIMUM DEPTH: 33 m

PROBLEM: Nuisance green algal blooms in the summer and fall. Taste and odor problems. Influx of domestic and agricultural wastewaters. **RESTORATION OBJECTIVE**: To reduce the algal production. To remove the organic materials. **RESTORATION METHODOLOGY**: The surface waters were treated with 300 kg of powdered limestone (95% CaO). The total cost was about $20 USA, $12 for the materials and $8 for the application (3 hrs). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Limestone application resulted in: (1) an increase in the pH to 10, (2) disappearance of the carbon dioxide, and (3) a halt in chlorophyll functioning. The algae were destroyed and carried to the lake bottom. Eight days after treatment the water clarity increased; the plankton were totally gone; and there no longer was a taste and odor problem. There were no apparent adverse effects. **REFERENCES**: Romeyer (pers. comm.).

LAKE NAME: Agras Flowage
LOCATION: 92 km W of Saloniki, West Macedonia, Greece
SURFACE AREA: 7 to 10 km^2
MAXIMUM DEPTH: 1.5 m

PROBLEM: Profuse reed growth *(Phragmites communis, Typha)* obstructing water flow through the power plant system. Canals to pressure tunnel blocked by *Potamogeton natans* and *Chara*. **RESTORATION OBJECTIVE**: To eliminate macrophyte growths that are deleterious to efficient operation of the power plant. **RESTORATION METHODOLOGY**: Swans were stocked in past years against *Potamogeton natans*, and ducks *(Netta rufina)*, for *Chara* control, with some success. Most recently (1965-67) several hundred nutria *(Myocastor coypus)* were brought in to help control the above-water vegetation; previously several mechanical harvesting attempts were unsuccessful and chemical control was unfeasible (the water outflow from the power plant is used agriculturally). These native South American (Argentina, Chile) animals feed extensively upon reed and sedge roots and buds and also make use of the stalks for nest building. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There was some conflict between the introduced nutria and the native muskrat population, but as the nutria became established and stripped away more and more of the above-water plant growth, the muskrats receded. As the nutria cleared areas of plant remains and the root network, large numbers of Chironomid larvae and zooplankton appeared. Areas of high fish catch now correspond to those of high nutria activity. Special feeding tables were set up to attract nutria to specific areas where clearing of reed growth was desired. This was highly successful and has resulted in settlement throughout most of the flowage area. These measures have proven at least partially successful in bringing the reed problem toward control. **REFERENCES**: Ehrlich (1969).

LAKE NAME: Velence
LOCATION: central Hungary
SURFACE AREA: 25.3 km^2
MAXIMUM DEPTH: 2.5 m

PROBLEM: Badly sedimented; and nuisance algal blooms in late summer. The water is unsuitable for recreational use. Other problems associated with over-fertility. **RESTORATION**

OBJECTIVE: To limit algae and macrophytes by domestic sewage diversion. To deepen the basin by removing the bottom deposits. To increase the open water areas by removing reeds. **RESTORATION METHODOLOGY**: A diversion canal around the lake is under construction (now 10 km long). Dredging is also in progress, about 280,000 m^3 sludge/year. Reeds were eradicated from about 15 ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In the parts of the lake which have been treated for five years, the water quality remains satisfactory through the summer. An excellent *Vaucheria dichotoma* covering has also developed on the sediments in the dredged areas of the lake. Nuisance planktonic algal growths were eliminated; in addition, *V. dichotoma* is a competitor of the macrophytes. **REFERENCES**: Springer (pers. comm.).

LAKE NAME: Two (2) ponds
LOCATION: Cuttack, India
SURFACE AREA: 224 and 1665 m^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of macrophytes. **RESTORATION OBJECTIVE**: To control macrophytes by application of the herbicide, copper sulfate (pelleted form). **RESTORATION METHODOLOGY**: The smaller pond was completely choked with *Nymphoides cristatum* (very abundant); *Limnophila heterophylla* (abundant), *Hydrilla verticillata, Alternanthera sessilis, Najas* sp. (common), *Ottelia alismoides,* and *Nymphaea* sp. (rare). Based on the results of laboratory experiments the dose selected was 45 kg/ha for each of four treatments at three day intervals. The other pond was thickly infested with *Nymphoides cristatum* (58% of the surface area). The bottom soil of the infested area was treated with five doses of 35 kg/ha each. The first four doses were applied on alternate days and the fifth dose on the 23rd day. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In the 224 m^2 pond, 80% of the *Hydrilla* and *Limnophila* floated to the surface three days after the first dose. Mature *Nymphoides* started uprooting four days after the last application and 80% of the marginal vegetation was uprooted at that time. The pond was cleared of macrophytes completely by the 57th day. In the 1665 m^2 pond, the macrophytes were eliminated within 68 days. Regrowth occurred for a short period but the pond was later completely free of vegetation. **REFERENCES**: Mitra (1970).

LAKE NAME: Ooty
LOCATION: Madras, India
SURFACE AREA: 34 ha
MAXIMUM DEPTH: 19 m

PROBLEM: Excessive eutrophication caused by storm water influx from a nearby town, and partial release of municipal wastes from a damaged pipeline. The pipes were laid along the lake margin, submerged. **RESTORATION OBJECTIVE**: To improve the undesirable, hypereutrophic conditions. **RESTORATION METHODOLOGY**: During the summer of 1966 water was discharged through a low level outlet. Complete drainage and bottom sediment removal followed by refilling was proposed for the future. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Although no supportive documentation was presented in the reference, the author indicated that low level discharge improved conditions somewhat. Various physical, chemical, and biological parameters were measured before treatment and therefore the necessary documentation was apparently available. **REFERENCES**: Sreenivasan (1969).

LAKE NAME: Emy Lough
LOCATION: Co. Monaghan, Ireland
SURFACE AREA: 55 ha
MAXIMUM DEPTH: 12.2–13.7 m

PROBLEM: Nutrient influx from intensive pig and poultry rearing units. Silt influx from a sand-washing plant. Algal blooms have occurred and there was a fishkill in this salmonid lake. **RESTORATION OBJECTIVE**: To prevent further nutrient input by providing adequate slurry storage facilities and by controlling slurry spreading. To prevent the discharge of silt into the lake. **RESTORATION METHODOLOGY**: Investigations are underway; the project is still in the pre-implementation stage. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Inland Fisheries Trust, Inc. (1972), Kennedy, Fitzmaurice, and Champ (pers. comm.).

LAKE NAME: Lough Ennell
LOCATION: Co. Westmeath, Ireland
SURFACE AREA: 14 km^2
MAXIMUM DEPTH: 27. 5 m

PROBLEM: Nuisance blue-green algal blooms caused by the continuous discharge of sewage into this productive, salmonid lake. **RESTORATION OBJECTIVE**: To provide a new sewage treatment plant with tertiary treatment in order to reduce the phosphate content of the effluent. **RESTORATION METHODOLOGY**: A new sewage treatment plant has been agreed upon, but construction has not yet begun. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Inland Fisheries Trust, Inc. (1972), Kennedy, Fitzmaurice, and Champ (pers. comm.), Kennedy and Fitzmaurice (1971).

LAKE NAME: Garadice Lough
LOCATION: Co. Leitrim, Ireland
SURFACE AREA: 3.6 km^2
MAXIMUM DEPTH: 16.8 m

PROBLEM: Very rapid eutrophication caused by the wash-in of material from a slurry storage lagoon (intensive pig-rearing unit) flooded by an exceptional rainstorm. **RESTORATION OBJECTIVE**: To provide adequate and storm-proof slurry storage facilities and to control slurry disposal in the drainage basin. **RESTORATION METHODOLOGY**: Investigations are underway by the Agricultural Advisory Services. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Inland Fisheries Trust, Inc. (1972), Kennedy, Fitzmaurice, and Champ (pers. comm.).

LAKE NAME: Inniscarra Reservoir
LOCATION: Co. Cork, Ireland
SURFACE AREA: 5.2 km^2
MAXIMUM DEPTH: 31 m

PROBLEM: Thermal stratification during the summer, resulting in the release of anaerobic water through the power turbines. The downstream channel supports an important salmonid fishery and a fishkill was possible. **RESTORATION OBJECTIVE**: To prevent thermal stratification and to increase the dissolved oxygen levels in the bottom waters. **RESTORATION METHODOLOGY**: In May, 1961, six "Aero-Hydraulic Guns", each 13.4 m in length, were installed at a depth of 26 m near the dam in order to oxygenate the water near the turbine intakes. **RESULTS (OR STATUS FOR ONGOING

PROJECTS): The summer of 1961 was relatively dry, and under normal circumstances the reservoir would have undergone severe stratification. Aeration and destratification considerably improved the dissolved oxygen levels near the dam; on only a few occasions did the dissolved oxygen levels drop below 5 mg/l. Normally, oxygen concentrations as low as 1-2 mg/l were experienced at the turbine intakes. **REFERENCES**: Water and Water Engineering (1962).

LAKE NAME: Lough Leane
LOCATION: Killarney, Co. Kerry, Ireland
SURFACE AREA: 20.2 km^2
MAXIMUM DEPTH: 64 m

PROBLEM: Eutrophic conditions, at least in part, arising from the addition of untreated domestic sewage. Resident population is 7000 but there are about 60,000 summer visitors. **RESTORATION OBJECTIVE**: To prevent the entry of the sewage into the lake. **RESTORATION METHODOLOGY**: A number of secondary treatment plants are under construction and should be operational by mid-1974. Cost data are not available. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Several physico-chemical and biological parameters are under investigation. Studies will continue after treatment. **REFERENCES**: Bracken (pers. comm.).

LAKE NAME: Lough Sheelin
LOCATION: Cos. Cavan, Meath, and Westmeath, Ireland
SURFACE AREA: 18.9 km^2
MAXIMUM DEPTH: 13.7 m

PROBLEM: Nuisance blooms of blue-green algae caused by the recent establishment of intensive pig-rearing units in the drainage basin. Serious problem in 1971. **RESTORATION OBJECTIVE**: To prevent the discharge of slurry into the streams and the run-off of nutrients by providing increased storage for slurry and limiting the spreading to summer months. **RESTORATION METHODOLOGY**: Increased slurry storage is being provided. The Agricultural Advisory Service is cooperating in research on the capacity of soil to absorb nutrients and in advising farmers on slurry disposal. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There was an improvement in lake water quality in 1972, but P and N levels in the tributaries are still excessive and will continue so until the objectives are fully achieved. **REFERENCES**: Inland Fisheries Trust, Inc. (1972), Kennedy, Fitzmaurice, and Champ (pers. comm.), Kennedy and Fitzmaurice (1971).

LAKE NAME: Lake Kinneret
LOCATION: Jordan Valley, Israel
SURFACE AREA: 170 km^2
MAXIMUM DEPTH: 42 m

PROBLEM: Nuisance Dinoflagellate blooms during winter and spring. Hypolimnetic oxygen depletion is also severe May through December. **RESTORATION OBJECTIVE**: To limit algal growth and to retard the rate of oxygen depletion in the hypolimnion. **RESTORATION METHODOLOGY**: The lake has been stocked with *Tilapia aurea* for the past 16 years; *Mugil cephalus*, for the past 12 years; and *Hypophtalmichthys maltrix*, for the past five years. A sewage diversion project around the lake has been completed and local sewage treatment in the drainage basin is being carried out. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are apparently inconclusive to date. **REFERENCES**: Prowse (1969), Serruya (pers. comm.; many publications are available).

LAKE NAME: Lake Trasmino
LOCATION: Umbria, Italy
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of *Phragmites communis*. **RESTORATION OBJECTIVE**: To eradicate the macrophyte with an herbicide. **RESTORATION METHODOLOGY**: The herbicide N.P. (60% sodium dichlorobutyric acid and 40% chlorinated fatty acids) was used once during the summer. The aerial parts of the plants were sprayed evenly. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The treatment was successful in eradicating *P. communis*. Chlorophyll formation was arrested and the rhizomes were devitalized. **REFERENCES**: Moretti et al. (1962).

LAKE NAME: Lake Biwa
LOCATION: Shiga Prefecture, Japan
SURFACE AREA: 680 km^2
MAXIMUM DEPTH: 104 m

PROBLEM: Rapid eutrophication caused by domestic sewage, industrial wastes, and agricultural runoff. Change in species composition, especially fish. Low DO. Algal blooms in spring and summer. Musty odor in the water (used as water supply for 10% of the total Japanese population). **RESTORATION OBJECTIVE**: To stop the eutrophication of the lake, largest in Japan. **RESTORATION METHODOLOGY**: A sewage pipe system will be installed along the southern basin of the lake (worse than the northern basin) and a sewage disposal plant will be constructed. This project was decided by government and congress in late 1972. The outflow from the disposal plant will be diverted to River Yodo. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Research started recently. Rapid changes in quality and quantity of plankton and benthos, together with transparency and oxygen contents were ascertained. This change is especially remarkable since 1968. A nutrient budget (N and P) is incorporated into the lake studies. Investigations will continue following diversion. **REFERENCES**: Inoue (pers. comm.), Japanese Association of Civil Engineers (1969, 1970, 1971), Mori (pers. comm.), Mori (1972), Tsuda (pers. comm.).

LAKE NAME: Lake Kasumi-ga-ura
LOCATION: Ibaragi Prefecture, Japan
SURFACE AREA: 178 km^2
MAXIMUM DEPTH: 7 m

PROBLEM: Blue-green algal blooms, preventing direct use of the water for drinking or industry. The eutrophication is believed to be induced by the influx of agricultural and domestic wastes. **RESTORATION OBJECTIVE**: To limit the planktonic algal growth so that the water can be used for drinking after simple treatment only. **RESTORATION METHODOLOGY**: The pre-treatment investigation has just begun. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Seki (pers. comm.).

LAKE NAME: Lake Shirakaba
LOCATION: Japan
SURFACE AREA: 35 ha
MAXIMUM DEPTH: 8.5 m

PROBLEM: Increasing eutrophication caused by domestic sewage produced at the lakeside resorts (1,500,000 to 2,000,000 visitors annually) and the dissolution of constituents from the bottom materials. **RESTORATION OBJECTIVE**: To reverse the trend toward eutrophication. **RESTORATION METHODOLOGY**: A decision has not yet been made. Sewage diversion out of the drainage basin and drainage of the impoundment are possibilities. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Limnological investigations of the impoundment, bottom deposits, and inflowing streams are continuing. **REFERENCES**: Koidsumi (pers. comm.), Kō-Shin-Etsu Branch of Japanese Society of Limnology (1970, 1971).

LAKE NAME: Lake Suwa
LOCATION: Japan
SURFACE AREA: 14.2 km^2
MAXIMUM DEPTH: 6.8 m

PROBLEM: Nuisance blue-green algae *(Microcystis aeruginosa)* induced by the influx of industrial wastes. **RESTORATION OBJECTIVE**: To limit planktonic algal growth by reducing the phosphorus and nitrogen concentrations. **RESTORATION METHODOLOGY**: A sewage system construction plan has been discussed for around the entire lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Limnological investigations are in progress. **REFERENCES**: Koidsumi (pers. comm.; many reports are available).

LAKE NAME: Campus Lake
LOCATION: Luala Lumpur, Malaysia
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Erosion and sediment deposition within the lake caused by urbanization of the drainage basin. **RESTORATION OBJECTIVE**: To restore the lake to its original state. Sedimentation has stopped with the decline in land development. **RESTORATION METHODOLOGY**: The lake has been drained and the sediment is currently being excavated in-the-dry. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Furtado (pers. comm.).

LAKE NAME: Lake Chapala
LOCATION: States of Jalisco and Michoaecan, Mexico
SURFACE AREA: 1120 km^2
MAXIMUM DEPTH: 17 m

PROBLEM: Periodic appearance of large growths of water hyacinths *(Eichornia crassipes)* and ever increasing reduction in famed "white fish" production. Also, increased cost of treatment for Guadalajara city water supply. High water turbidity and excessive sedimentation causing the lake bed to prematurely fill up. **RESTORATION OBJECTIVE**: To reduce the nuisance conditions caused by macrophyte growth; to increase the fish production; and to retard sedimentation of the lake. **RESTORATION METHODOLOGY**: An intensive research program is underway to determine the primary sources of pollutants, initiated December, 1972. Research is being financed by the Mexican Federal Government through the Ministry of Water Resources at a cost of $200,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The first phase of research concluded that the main sources of pollution were the Rio Lerma (a highly polluted river that discharges to Lake Chapala) and agricultural runoff from the Cienega de Chapala. The second phase is presently getting underway. **REFERENCES**: Aquirre (pers. comm.), Instituto, de Ingeniería, Universidad Nacional Autónoma de México (in press).

LAKE NAME: Two (2) reservoirs
LOCATION: Zeeuws-Vlaanderen, Netherlands
SURFACE AREA: 22 ha each
MAXIMUM DEPTH: 11 m each (full pool)

PROBLEM: Blue-green algal growths in three water supply reservoirs causing water quality problems. **RESTORATION OBJECTIVE**: To control the algal growth. **RESTORATION METHODOLOGY**: Two of the reservoirs, nearly identical in size and depth were aerated using a 150 m long perforated air line placed on the bottom in the corner of each rectangular reservoir. Air was supplied to each reservoir at a rate of 33 l/sec. A third reservoir, about 2/3 the size of the other two, but with the same depth served as a control. Test Reservoir I was circulated intermittently for short periods for four months in the summer of 1968, whereas Test Reservoir II was circulated continuously during the same period. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The algal growth pattern in Test Reservoir I was nearly identical to the control, the intermittent mixing had no apparent effect on the growth and decline of *Anabaena.* Also a *Microcystis aeruginosa* bloom developed in the Test Reservoir I near the end of the summer which did not appear in the control. Isothermal conditions developed in the intermittently mixed reservoir slightly earlier than in the control. In Test Reservoir II, no algal species developed in large numbers until the end of July, at which time blue-green algae reached bloom proportions. *Aphanizomenon flos-aquae* was most prominent in July and August, and a bloom of *Microcystis* in the latter part of August was followed by a tremendous growth of the blue-green *Gomphosphaeria aponina* and the diatom *Cylotella comta.* Test Reservoir II stayed isothermal during the entire period. Although the experiment was conceived with the idea that mixing would carry algal cells out of the photic zone for at least short periods of time and hence retard their growth, the photic zone may have extended to the bottom of the reservoirs during the test. Water depths declined to about 6 m by the end of the test and mixing in Test Reservoir II may have promoted algal growth. **REFERENCES**: Knoppert et al. (1970).

LAKE NAME: Brielse Meer
LOCATION: Zuid Holland, Netherlands
SURFACE AREA: 3.7 km^2
MAXIMUM DEPTH: 18 m (mean depth, 6.3 m)

PROBLEM: Blue-green algal blooms during summer stratification. Eutrophication due to the inflow of Rhine River water and domestic sewage **RESTORATION OBJECTIVE**: To limit the phytoplankton growth by lowering the phosphate content of the inlet water with iron. **RESTORATION METHODOLOGY**: Iron application began in March, 1972 at 2 mg Fe/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Physico-chemical and biological effects are being studied; analyses are in progress. **REFERENCES**: Peelen (pers. comm.; plankton report in progress; physico-chemical reports and cost estimates are available from Sr. R. Klomp, Dept. of Roads and Waterways, Roadhuisstraatg, Sheer Arendskerke, Netherlands), Peelen (1969).

LAKE NAME: Drontermeer

LOCATION: central Netherlands
SURFACE AREA: 6 km^2
MAXIMUM DEPTH: 5 m

PROBLEM: Eutrophic conditions induced by domestic and dairy wastewaters. Nuisance blue-green algal blooms (composed of 90–100% *Oscillatoria agardhii*); decreased fish productivity; and high BOD and COD. **RESTORATION OBJECTIVE**: To limit the planktonic algal growth by reducing the phosphorus concentration and the input of organic materials. **RESTORATION METHODOLOGY**: Since 1972 the effluent from a sewage treatment plant (60,000 inhabitant equivalents) has been treated with ferric chloride. Previously, there was a basin for aeration and sedimentation of the effluent. Biological waste treatment and lake bottom dredging are also under consideration. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Berger (1970), Segeren (pers. comm.).

LAKE NAME: Honderd en Dertig

LOCATION: Netherlands
SURFACE AREA: 2.2 km^2
MAXIMUM DEPTH: 26 m

PROBLEM: Recently completed pumped storage water supply reservoir; currently (1973) filling with polluted water from the River Meuse. Without remedial measures, water quality deterioration due to algal blooms and hypolimnetic oxygen depletion can be expected. **RESTORATION OBJECTIVE**: To control the water quality by limiting algal growth and preventing anaerobiosis. **RESTORATION METHODOLOGY**: The reservoir will be maintained in a completely mixed condition by aeration. Air will be introduced at a rate of 12-24 m^3/min from several locations within the reservoir. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Oskam (pers. comm.), Oskam (1971).

LAKE NAME: Loosdrechtse Plassen

LOCATION: near Amsterdam, Netherlands
SURFACE AREA: 23.3 km^2
MAXIMUM DEPTH: 2–3 m

PROBLEM: Blooms of blue-green algae; disappearance of bottom flora and fauna; and decrease of waterflow. Eutrophication induced by increasing influx of wastewater, increasing recreation, and change in water management. **RESTORATION OBJECTIVE**: To limit the planktonic algal growth by improving water management, diverting of wastewater, and reducing phosphate. **RESTORATION METHODOLOGY**: The diversion of wastewater from the surrounding villages to outside the lake region has been accomplished or nearly so. The pumping machines of the polder have been enlarged in an attempt to increase the water level in the lake area. And there is a plan to divert water from the Amsterdam-Rhine canal (better water quality) into the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment has been insufficient to prevent nuisance algal growth. Bottom flora have not reappeared. **REFERENCES**: Leentvaar (pers. comm.).

LAKE NAME: Maarsseveen Lake

LOCATION: Netherlands
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Anaerobic hypolimnia, dense algal growths, and poor water quality expected in future water supply reservoirs. **RESTORATION OBJECTIVE**: To determine the degree of destratification necessary for water quality control and the most effective destratification equipment. **RESTORATION METHODOLOGY**: A full-scale experiment was conducted in Maarsseveen Lake. Initially, a 170 m long perforated tube was placed at a depth of 19 m across the entire lake. Air was supplied to both ends of the tube with shore-mounted compressors. The tube was later replaced with a single diffuser placed in the deepest part of the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Air was released from the perforated tube for a period of eight days at a rate of 8.5 l/sec during late July, 1967. The air flow rate was then increased to 41 l/sec and maintained for a period of one month. At the higher rate, the thermocline sank steadily until it reached the depth of the tube after 19 days of aeration. Using the single diffuser, the lake was completely destratified. The destratification efficiency of the perforated tube was slightly higher than that of the single diffuser, and with both techniques, the quantity of water circulated decreased as the thermocline approached the level of air release. Destratification had no apparent effect on the sparse algal population. **REFERENCES**: Knoppert et al. (1970).

LAKE NAME: Petrusplaat

LOCATION: Netherlands
SURFACE AREA: 1.1 km^2
MAXIMUM DEPTH: 17 m

PROBLEM: Recently completed water supply reservoir; currently (1973) being filled with polluted water from the River Meuse. Without remedial measures, water quality deterioration due to algal blooms and hypolimnetic oxygen depletion can be expected. **RESTORATION OBJECTIVE**: To control the water quality by limiting algal growth and preventing anaerobiosis. **RESTORATION METHODOLOGY**: The reservoir will be maintained in a completely mixed condition by aeration; air will be introduced at a rate of 6-12 m^3/min from several locations within the reservoir. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Oskam (pers. comm.), Oskam (1971).

LAKE NAME: Veluwe Randmeer

LOCATION: Netherlands
SURFACE AREA: 20 km^2
MAXIMUM DEPTH: 5 m

PROBLEM: Nuisance blue-green algal blooms; persistence of *E. coli* due to decreased light penetration. Recipient for domestic sewage effluent. **RESTORATION OBJECTIVE**: To inhibit algal growth by reducing the phosphorus levels. **RESTORATION METHODOLOGY**: In conjunction with tertiary sewage treatment (Fe precipitation), dredging and/or flushing with polder water are planned to remove the phosphorus already present in the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A pilot study is planned for 1973. **REFERENCES**: Golterman (pers. comm.).

LAKE NAME: Veluwemeer North

LOCATION: central Netherlands
SURFACE AREA: 34 km^2
MAXIMUM DEPTH: 6 m

PROBLEM: Eutrophic conditions induced by domestic and dairy wastewaters. Nuisance blue-green algal blooms (composed of 90-100% *Oscillatoria agardhii*); decreased fish productivity; and high BOD and COD. **RESTORATION OBJECTIVE**: To limit the planktonic algal growth by reducing the phosphorus concentration and the input of organic materials. **RESTORATION METHODOLOGY**: Since 1972, the effluent from a sewage treatment plant (150,000 inhabitant equivalents) has been treated with ferric chloride for phosphorus removal. Treatment is limited for the time being to 7 m^3/hr due to the lack of a sedimentation basin. In the future, the dairy and livestock wastes will also be collected and treated prior to discharge into the lake. In addition, biological waste treatment and lake bottom dredging are under consideration. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Berger (1970), Segeren (pers. comm.).

LAKE NAME: Many lakes
LOCATION: New Zealand
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Excessive growth of exotic macrophytes and presence of soluble iron causing blockage of penstock openings and interfering with recreation. Some blue-green algal blooms. **RESTORATION OBJECTIVE**: To control the macrophytes and prevent their further spread. **RESTORATION METHODOLOGY**: A number of methods have been tried including: a) harvesting; b) chemicals (diquat); c) grass carp *(Ctenopharyngodon idellus)*; d) land use management; and e) diversion of sewage effluent at one of the lakes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Harvesting has been abandoned for the moment as being too expensive. Diquat is used extensively with success. Sewage diversion is nearly complete. Land use practices are implemented in some areas. Grass carp are now being evaluated. **REFERENCES**: Chapman (pers. comm.), White (pers. comm.; several unpublished and published reports are available).

LAKE NAME: Two (2) lakes
Hayes
Johnson
LOCATION: near Queenstown, Otago, New Zealand
SURFACE AREA / MAXIMUM DEPTH:
Hayes (2.8 km^2) / 33 m
Johnson (28 ha) / 27 m

PROBLEM: Nuisance blue-green algal blooms in both lakes. Eutrophic conditions apparently aggravated by agricultural practices in the drainage basins. **RESTORATION OBJECTIVE**: To limit the algal growth and to improve the dissolved oxygen content of the hypolimnion by reducing the influx of phosphorus (and possibly of nitrates). **RESTORATION METHODOLOGY**: Irrigation water, rich in phosphorus, will be diverted from Lake Hayes; both lakes will be partially flushed with nutrient-poor water from a nearby river (L. Hayes) and irrigation race (L. Johnson). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment was proposed as a result of a baseline survey over a period of 26 months (December 1969-February 1972). **REFERENCES**: Burns (pers. comm.; several reports are in preparation), Burns and Mitchell (in press).

LAKE NAME: Two (2) lakes
Lake Rotoiti
Lake Rotorua
LOCATION: New Zealand
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Large concentrations of *Lagarosiphon major* (Ridley) Moss, a native of South Africa, due to enrichment by domestic sewage. **RESTORATION OBJECTIVE**: To control the macrophytes with an arsenical herbicide. **RESTORATION METHODOLOGY**: Two plots, 0.4 ha each, were situated in deep (4 m) and shallow (2 m) weed beds in Lake Rotorua and one in a shallow (2 m) area in Lake Rotoiti. The weeds, bottom deposits, and fauna were sampled before and after the application of sodium arsenic. Sufficient herbicide was air-dropped in July, 1961 to yield an average concentration of 10 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Herbicide application did not significantly effect the flora or fauna. One possible cause of the failure may have been due to the relatively cool water temperatures. This could have reduced metabolism and the rate of absorption and translocation of the herbicide. Another factor may have involved an increased tolerance to arsenic, since relatively high arsenic levels were found in the bottom deposits and in the tissues of the plants in these lakes prior to treatment. The concentration of arsenic in the water was 5 mg/l one hour after application, 1 mg/l after 24 hrs, and 0.006 mg/l after one week. **REFERENCES**: Fish (1963).

LAKE NAME: Cosseys Reservoir
LOCATION: Auckland, New Zealand
SURFACE AREA: 1.2 km^2
MAXIMUM DEPTH: 29 m

PROBLEM: Unsatisfactory levels of dissolved oxygen, iron, manganese, odor, and pH due to thermal stratification. The reservoir is used for water supply. **RESTORATION OBJECTIVE**: To improve the water quality in the most economical way. **RESTORATION METHODOLOGY**: A 91 m long perforated tube was installed near the bottom in order to aerate and destratify the lake. Air was supplied from a shore-based electric compressor. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During the first summer of operation, the lake was completely destratified in one month of continuous operation. Stratification and water quality have been satisfactorily controlled in subsequent years with intermittent operation. **REFERENCES**: Ogilvie (pers. comm.).

LAKE NAME: Lake Rerewhakaitu
LOCATION: Rotorua, New Zealand
SURFACE AREA: 6.5 km^2
MAXIMUM DEPTH: 31 m

PROBLEM: Eutrophication interfering with recreational uses of the lake. This condition is recent, following farm development during the past 15 years. **RESTORATION OBJECTIVE**: To reduce erosion in the drainage basin and to limit the nutrient influx to the lake. **RESTORATION METHODOLOGY**: Stabilization of the shoreline area by tree planting is 50% complete. A survey of the drainage basin was completed in 1972, but a farm survey is still in progress. Anti-erosion measures on pastures and diversion of wastes from milking sheds, etc. should reduce the present nutrient load. It is hoped to make a significant nutrient reduction by 1974. This should rapidly limit the phytoplanktonic production, because the sediments will only release nutrients slowly. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Monitoring of the lake to establish its nutrient budget and the identification of nutrient sources in its drainage basin are not yet complete. Limitation of large nutrient sources cannot begin before the end of 1973. Results of these treatments will be analyzed during 1974. **REFERENCES**: Chapman (pers. comm.), Fish (pers. comm.).

LAKE NAME: Gjersjøen
LOCATION: near Oslo, Norway
SURFACE AREA: 2.7 km^2
MAXIMUM DEPTH: 64 m

PROBLEM: Nuisance blue-green algal blooms and winter fishkills caused by oxygen depletion. Eutrophic conditions apparently induced by domestic waste from a population of about 15,000. The drainage area is composed of woods and cultivated land; about 19% is agricultural land. **RESTORATION OBJECTIVE**: To limit the planktonic algal growth and to improve the dissolved oxygen conditions by reducing the phosphorus concentrations. **RESTORATION METHODOLOGY**: The wastes were diverted to a treatment plant with an outlet outside of the drainage basin. Diversion began January, 1972. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There had not yet been a change in the lake. The concentrations of P and N in the tributaries, however, now are only 1/4 of what they were before. The hydraulic residence time is estimated to be 1.5 years. **REFERENCES**: Holtan (pers. comm.), Holtan (1972).

LAKE NAME: Kolbotnvatn
LOCATION: Oslo, Norway
SURFACE AREA: 30.3 ha
MAXIMUM DEPTH: 18.5 m (mean depth, 10.3 m)

PROBLEM: Eutrophic conditions due to the continuing influx of domestic wastes. Nuisance algal blooms, DO depletion, H_2S generation, and winter fishkills. **RESTORATION OBJECTIVE**: To reduce the phosphorus concentrations in order to limit algal growth and improve dissolved oxygen conditions. **RESTORATION METHODOLOGY**: An Atlas-Copco "Limno" hypolimnetic aeration unit was installed in April, 1973. The total cost was about $20,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The equipment has been operated approx. 50% of the time. The temperature profile was unaffected and the dissolved oxygen levels were maintained at 3-6 mg/l in the bottom waters. **REFERENCES**: Atlas Copco AB (pers. comm.), Holtan (pers. comm.).

LAKE NAME: Gatun Lake
LOCATION: Canal Zone, Panama
SURFACE AREA: 454 km^2
MAXIMUM DEPTH: 26 m

PROBLEM: Overabundant macrophytes obstructing boat traffic and providing mosquito breeding sites. **RESTORATION OBJECTIVE**: To reduce the quantities of floating and submergent macrophytes. **RESTORATION METHODOLOGY**: Macrophytes (primarily *Eichornia crassipes)* are trapped behind floating booms and mechanically removed from the shipping lanes. Limited and carefully controlled applications of herbicides have been undertaken in other areas. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The objectives have been achieved but continuous year-round surveillance and activity has been necessary. Macrophyte control measures have been needed during almost the entire period of canal operation. **REFERENCES**: Romaneski (pers. comm.).

LAKE NAME: Two (2) lakes
Długie Lake
Starodworski Lake
LOCATION: Poland
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Unknown; no information received. **RESTORATION OBJECTIVE**: Unknown, no information received. **RESTORATION METHODOLOGY**: The conditions in Starodworski Lake will be improved using compressed air. A restoration program is now being planned for D lugie Lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Sikorowa (pers. comm.).

LAKE NAME: Lake Kortowo
LOCATION: Olsztyn, Poland
SURFACE AREA: 89.7 ha (two basins of nearly equal size)
MAXIMUM DEPTH: 17.2 m

PROBLEM: Severe hypolimnetic DO depletion during the summer, thereby decreasing the lake's value as a fishery. Eutrophication resulting from agricultural and domestic wastes. **RESTORATION OBJECTIVE**: To restore the hypolimnetic condition necessary to sustain a fishery. **RESTORATION METHODOLOGY**: In 1955 the outlet was dammed and an outflow pipe installed in the south basin down to 13 m. The north basin was used as a control. The system began operation on 5 July, 1956 after summer stratification had become established. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After 10 days the thermocline sank significantly and the temperature at 13 m increased from 7° to 14° C. DO consumption increased due to increased temperatures. After 40 days the epilimnion extended to 13-14 m; the thermocline began at that depth and had a temperature gradient of 6.4° C. The DO levels were 8 mg/l at 8 m, 3 mg/l at 12 m, and 1 mg/l at 14 m; previously total depletion existed at about 8 m. The phyto- and zooplankton populations occurred at increased depths and the maxima were observed earlier in the season as compared to the north basin. Sulfides nearly disappeared from the bottom waters. The outflow was characterized as a small river in size. **REFERENCES**: Olszewski (1961, 1971). Sikorowa (pers. comm.; many reports have been published).

LAKE NAME: Lake Warniak
LOCATION: Masurian District, Poland
SURFACE AREA: 38.4 ha
MAXIMUM DEPTH: 3.7 m

PROBLEM: Macrophytes covering the lake; 13% with emergents and the rest, submergents. Secchi disc varied from 1.7 m in the summer to 2.9 m in the winter. **RESTORATION OBJECTIVE**: To determine the effect of an artificially increased fish stock on the biocenosis. **RESTORATION METHODOLOGY**: The lake was divided into two or three parts with various fish concentrations (by stocking); enclosures (1-100 m^2) without fish were also put into the lake. Benthophagous fish were stocked beginning in 1967. The biomass in the lake increased by 1969 from 0 to 2500 kg for carp and from 0 to 300 kg for bream. Trench (benthophagous) and crucian carp (planktophagous) naturally occurred in the lake. By 1969 the biomass of the three benthophagous species was 200 kg/ha or double the pre-stocking level. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Gross primary production decreased as the fish stock increased. The biomass of phytoplankton was reduced and consisted of a greater percentage of nannoplankton. The average numbers of zooplankton increased slightly as did the percentage of small filtrators. The fertility and average length of all Cladocerans and rotifers also increased. The biomass of fauna living on macrophytes decreased along with the benthos biomass and density (esp. the benthic predators). Visual observations indicated a decrease in area covered with submergents. The changes were thought to be linked to the mixing and bottom disturbance resulting from the feeding of the benthophagous species. The results indicate that water quality can be influenced by management of the fish stock; this type of work is continuing with a bigger and more diversified fish stock. **REFERENCES**: Kajak (pers. comm.; many publications are available), Kajak et al. (1972).

LAKE NAME: Several ponds
LOCATION: Mayaguez, Puerto Rico
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Heavy growths of macrophytes, primarily *(Nymphaea ampla)*, providing habitat for the snail *Australorbis Glabratus* (carrier of *Schistosoma mansoni)*. **RESTORATION OBJECTIVE**: To destroy the host food plant. **RESTORATION METHODOLOGY**: The snail *Marisa cornuarietis* was introduced to feed on and restrict the macrophyte growths. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The snails essentially eradicated vegetation in 51-75 weeks, depending on the pond. **REFERENCES**: Radke et al. (1961).

LAKE NAME: Two (2) lakes
Lake Carriazo
Lake Cidra
LOCATION: near San Juan, Puerto Rico
SURFACE AREA:
Lake Carraizo (81 km^2)
Lake Cidra (21.1 km^2)
MAXIMUM DEPTH: ---

PROBLEM: Excessive water hyacinth *(Eichornia crassipes)* growth and fishkills caused by oxygen depletion. Eutrophic conditions induced mainly by secondary effluents from wastewater treatment plants and industrial wastes. The lakes are used for municipal water supply. **RESTORATION OBJECTIVE**: To control the macrophyte growth and to improve the sanitary conditions of the lakes. **RESTORATION METHODOLOGY**: Mechanical removal of water hyacinths has begun at both lakes. A regional tertiary wastewater treatment plant is planned to serve five municipalities discharging secondary effluents into Lake Carraizo. A strict surveillance of the drainage basins is conducted to see that the established water quality standards are complied with; industry was forced to apply wastewater treatments. The introduction of plant eating fish (white amur, *Ctenopharyngodon idellus)* is planned for the future. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Mechanical removal of water hyacinths has reduced the nutrient levels at both lakes; although their removal has promoted algal growth. This is a result of increased light penetration into the lakes. **REFERENCES**: Goitia (pers. comm.).

LAKE NAME: Three (3) hydroelectric lakes
Lake Kyle
Lake Ngesi
Umshandige Dam
LOCATION: central Rhodesia
SURFACE AREA:
Lake Kyle (91 km^2)
Lake Ngesi (5.8 km^2)
Umshandige Dam (4.4 km^2)
MAXIMUM DEPTH: ---

PROBLEM: Reduced water holding capacity, hampered commercial and sport fisheries and water quality problems (low DO) due to macrophyte growths. **RESTORATION OBJECTIVE**: To reduce the macrophyte abundance. **RESTORATION METHODOLOGY**: Two fish species, *Tilapia melanopleura* and *T. mossambica*, were introduced into the lakes to consume the macrophytes. The cost was very low, because the fish were available in nearby waters. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were successfully controlled, but to the detriment of other members of the aquatic community. Other species of fish and waterfowl were reliant on the presence of macrophytes for food or nesting. **REFERENCES**: Junor (1969).

LAKE NAME: Lake McIlwaine
LOCATION: Robert McIlwaine National Park, Salisbury, Rhodesia
SURFACE AREA: 26.3 km^2
MAXIMUM DEPTH: 27 m

PROBLEM: Blue-green algal blooms (mainly *Anacystis cyanea* and *A. flos-aquae);* occasional fishkills in summer since 1969. Infestation by water hyacinth *(Eichornia crassipes)*. Water purification problems. Eutrophic conditions resulting from inflow of treated urban sewage. **RESTORATION OBJECTIVE**: To halt eutrophication by reducing the inflow of nutrients; and to control the water hyacinths. Pollution effects are temporarily ameliorated by good rainy seasons and it is hoped that improved sewage treatment will rectify the conditions. **RESTORATION METHODOLOGY**: Advanced wastewater treatment will be accomplished by utilizing the conventionally treated effluent for crop irrigation. Other methods of nutrient removal from effluents (phosphorus and nitrogen) are under investigation. Attempts to control the hyacinths are being made by hand removal and limited treatment with herbicide. Herbivorous fish, *Tilapia melanopleura* and *T. mossambica*, have also been introduced into the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Nutrient removal studies are still in the pilot stage. The phased program of reduction of inflow will result in total curtailment except for excessive flows by 1975. Close settlement along the inflowing rivers is now being limited. Water hyacinth control has been achieved and further investigations on biological control are being undertaken. *Tilapia* did a good job of control, but there may have been some detrimental effect on other members of the aquatic community. **REFERENCES**: Falconer (1970), Marshall (1970), Marshall and Falconer (in press a and b), Marshall and Mitchell (in press), Munro (1966), van der Lingen (pers. comm.), van der Lingen (1960), Williams (1970).

LAKE NAME: Sletar Reservoir
LOCATION: Singapore
SURFACE AREA: 3.2 km^2
MAXIMUM DEPTH: 17 m

PROBLEM: Eutrophic conditions due to the increasing influx of nutrients. The rapid growth of algae, especially blue-greens, was one of the factors causing recent, mass fish mortalities. **RESTORATION OBJECTIVE:** To improve the water quality by reducing the nutrient levels and algal concentrations through chemical, physical, and biological means. **RESTORATION METHODOLOGY:** Copper sulfate has occasionally been carefully applied to areas of excessive algal concentrations. The factor(s) stimulating blue-green algal growths, especially *Microcystis*, are being determined in the reservoir. A pilot experiment will soon be carried out involving the damming off of one of the arms of the reservoir. The dammed area will act as a "sedimentation pond" in which the nutrient-rich incoming water will be retained and purified by various means. Certain aquatic plants will be introduced to remove nutrients from the water and the silver carp *(Hypophthalmichthys molitrix)* will be stocked to control algal growth. These plants and fish have been or will be also introduced into the main body of the reservoir. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Copper sulfate is effective in controlling the algae, but it is a temporary solution (algal regrowth will occur) and must be used cautiously (toxic to non-target species at high concentrations). The other experiments are in progress and results are not now available. **REFERENCES:** Choon and Ling (pers. comm.).

LAKE NAME: Gorengab Dam
LOCATION: Windhoek, South Africa
SURFACE AREA: ---
MAXIMUM DEPTH: 7.6 m

PROBLEM: Hypolimnetic oxygen depletion in the summer of 1962; extremely poor quality water available for municipal supply. **RESTORATION OBJECTIVE:** To improve the dissolved oxygen levels in the bottom waters and provide a dependable, high-quality water supply. **RESTORATION METHODOLOGY:** A local shop-built air-lift pump was installed in the reservoir about 9 m away from the intake tower in 6 m of water. Discharge of the pump was estimated at 4×10^6 l/day. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Operation of the pump caused an immediate increase in the dissolved oxygen content of the surface waters from 3 to 11 mg/l. A gradual reduction followed and after 10 days of operation, dissolved oxygen concentrations near the pump ranged from 5 mg/l at the bottom to 8 mg/l near the surface. The operation of the pump apparently caused an immense algal bloom in the reservoir but there was a decrease in the amount of chlorine necessary for water treatment. **REFERENCES:** Kolbe (1964).

LAKE NAME: Hartbeespoort Dam
LOCATION: Transvaal, South Africa
SURFACE AREA: 12.9 km^2
MAXIMUM DEPTH: 42.7 m

PROBLEM: Excessive growth of *Microcystis aeruginosa* causing aesthetic problems, recreational problems, and drinking water problems. **RESTORATION OBJECTIVE:** To limit the growth of *Microcystis aeruginosa* and other planktonic algae by either nutrient removal or other techniques. **RESTORATION METHODOLOGY:** Biological, biological/chemical, or chemical removal of nitrogen and phosphorus in sewage effluents are under consideration. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Algal bioassays have shown nitrogen to be the primary limiting nutrient. Phosphorus is the secondary limiting nutrient. Nutrient budgets are being constructed to predict the effect of nutrient removal. Removal techniques are being evaluated. **REFERENCES:** Toerien (pers. comm.), Toerien and Steyn (1973).

LAKE NAME: Rietvlei Dam
LOCATION: Transvaal, South Africa
SURFACE AREA: 3 km^2
MAXIMUM DEPTH: 13.7 m

PROBLEM: Blooms of *Anabaena circinalis.* **RESTORATION OBJECTIVE:** To limit the growth of *Anabaena circinalis* through phosphorus removal or sewage diversion. **RESTORATION METHODOLOGY:** Restoration measures will involve either advanced wastewater treatment (biological, biological/chemical, or chemical removal of phosphorus in sewage effluents) or diversion of sewage effluents. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Although nitrogen is limiting the growth of green algae, a serious bloom of nitrogen fixing *Anabaena circinalis* occurs during the summer. Phosphorus removal from sewage effluents is being investigated as a means of limiting the growth of the nitrogen fixers. Nutrient budgets are being constructed and phosphorus removal techniques are being evaluated. **REFERENCES:** Toerien (pers. comm.), Toerien and Steyn (1973).

LAKE NAME: Roodeplaat Dam
LOCATION: Transvaal, South Africa
SURFACE AREA: 6 km^2
MAXIMUM DEPTH: 61 m

PROBLEM: Excessive growth of *Microcystis aeruginosa* causing aesthetic and recreational problems. **RESTORATION OBJECTIVE:** To limit the growth of *Microcystis aeruginosa* and other planktonic algae by either nutrient removal or other techniques. **RESTORATION METHODOLOGY:** Biological, biological/chemical, or chemical removal of nitrogen and phosphorus in sewage effluents is the most likely restoration technique. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Algal bioassays have shown nitrogen to be the primary limiting nutrient. Phosphorus is the secondary limiting nutrient. Nutrient budgets are being constructed to predict the effect of nutrient removal. Removal techniques are being evaluated. **REFERENCES:** Toerien (pers. comm.), Toerien and Steyn (1973).

LAKE NAME: Twelve (12) lakes
eight (8) lakes in Jönköping County,
Araslövssjön,
Hammarsjön,
Hemfjärden,
Oxhults o Valsverksdammarna

LOCATION: Sweden
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Unknown. No information was received. **RESTORATION OBJECTIVE:** Unknown. No information was received. **RESTORATION METHODOLOGY:** The National Swedish Environment Protection Board has funded the limnological investigations of these lakes since 1968. The data are being taken prior to a planned restoration attempt, although the restoration technique has not yet been selected in most cases. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not available. **REFERENCES**: Carlsson (pers. comm.).

LAKE NAME: Seventeen (17) lakes
LOCATION: Sweden

County	Lake	Area, km²	County	Lake	Area, km²
AB	Malmsjön	1	S	Kyrkviken	5.9
AB	Uttran*	3.2	S	Molkomsjön	5.1
C	Mälaren (in part)*	98	U	Ramsjön	0.4
D	Sillen	8.1	W	Gåran	0.2
D	Djulösjön	1.3	W	Glaningen	0.6
E	Boren	28.4	X	Näsbysjön	3
F	Ryssbysjön	2.8	Y	Veckefjärden	2.4
G	S. and N. Bergundasjön	4.2	Z	S. Åsvalltjärn	0.02
			BD	Ala Lombolo	0.35

*more detail available; see separate, individual listings.

PROBLEM: Problems associated with excessive eutrophication present or rapidly developing in these lakes. **RESTORATION OBJECTIVE**: To study the course of lake recovery resulting from sewage diversion or improved wastewater treatment. **RESTORATION METHODOLOGY**: The majority of the lakes listed above will receive reduced nutrient input through advanced wastewater treatment; chemical treatment will include the addition of aluminum sulfate, lime, or some iron compound. In a few lakes, diversion will be implemented. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The investigations in most cases commenced in 1972. Nutrient loadings are being measured, algal bioassays are being conducted, and a variety of water quality parameters are being monitored within the lakes. The sewage treatment plant effluents are also being examined periodically. **REFERENCES**: Forsberg (pers. comm.), Forsberg and Forsberg (1973), Forsberg et al. (1972).

LAKE NAME: Ånge Lake
LOCATION: Sweden
SURFACE AREA: 4 ha
MAXIMUM DEPTH: 6 m

PROBLEM: Extremely unproductive; no fish and a sparse plankton and benthos population; water clarity less than 40 cm. The upper layers of the sediment contained over 25% oil due to a long history of pollution from a locomotive workshop. **RESTORATION OBJECTIVE**: To remove the oil from the sediments. **RESTORATION METHODOLOGY**: The upper two meters of the sediments were agitated using a chain harrow in conjunction with compressed air jets. The released oil floated to the surface, where it was absorbed with mineral wool. Additional mineral wool was placed in a vertical barrier around the shore to prevent contamination of the shoreline areas. After the entire lake bottom had been treated, the oil-soaked mineral wool was collected with floating booms and towed to a shore incinerator. Total cost of the project was $100,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The oil content of the sediments was reduced to less than 2%, and the oil content of the water was 0.47 mg/l two years after treatment. The oil remaining in the sediments is probably strongly absorbed and will not be transferred to the water. The water clarity increased to 3.0 m, and plankton are much more abundant. Sea-birds have reappeared on the lake and stocked fish have survived, although their meat has an oily flavor. **REFERENCES**: Jerbo (pers. comm.), Jerbo (1973).

LAKE NAME: Balsjön
LOCATION: central Sweden
SURFACE AREA: 30 ha
MAXIMUM DEPTH: 11 m

PROBLEM: Influx of wastewater from a dressing plant for magnetite and hematite. As a result the lake is very turbid and there is constant sedimentation of fine-grained particles. This has caused a biologically sterile condition. **RESTORATION OBJECTIVE**: To determine the effect of a cessation of wastewater influx to the lake. **RESTORATION METHODOLOGY**: In fall, 1967 the dressing plant closed down. The conditions in Lake Balsjön and a control lake were studied for a couple of years before and after the closing. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Initially the turbidity and color were over 10 and 20 times, respectively that of the control lake. The Secchi disk was visible to a depth of only a few centimeters. DO levels were high, although autotrophs were limited to the top few centimeters. Zooplankton, bottom fauna, and macrophytes were absent. Two years after the closing, the turbidity was still about four times that of the control, but the color values were similar. Secchi disk readings increased to two meters. The DO concentration near the bottom decreased to 17% saturation. The phytoplankton increased in abundance and diversity but was dominated by a few species. Several zooplankton species were present at low population levels; the bottom fauna community was also starting to develop. The iron, pH, and specific conductance levels were reduced after the closing; however, there was no change in nitrogen and phosphorus **REFERENCES**: Ahling (1970).

LAKE NAME: Brunnsviken
LOCATION: Stockholm-Solna, Sweden
SURFACE AREA: 1.5 km²
MAXIMUM DEPTH: 14 m

PROBLEM: Recipient of municipal wastes until recently. The blue-green algae *Oscillatoria* reaches bloom proportions and occasionally hydrogen sulfide in the bottom waters reaches the surface. **RESTORATION OBJECTIVE**: To maintain oxygen in the bottom waters and to reduce nutrient recycling into the trophogenic zone. **RESTORATION METHODOLOGY**: The municipalities of Stockholm and Solna purchased four Atlas-Copco "Limno" hypolimnetic aeration units cooperatively. Total cost was about $48,000 USA, and operating costs are estimated at $10,000/year. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The units were installed in December, 1972 and were placed in operation in January, 1973. Results are unavailable at this time. **REFERENCES**: Atlas Copco AB (pers. comm.), Cronholm (pers. comm.), Karlgren (pers. comm.; in-house mimeographed memoranda are available).

LAKE NAME: Edsviken
LOCATION: Sollna, Danderyd, and Sollentuna
SURFACE AREA: 3.6 ha
MAXIMUM DEPTH: 20 m

PROBLEM: Hydrogen sulfide formation in the oxygen-deficient bottom waters and blue-green algal *(Oscillatoria)* blooms at the surface. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen conditions in the bottom waters; to reduce the phosphorus concentrations in order to control algal growth and increase water quality. **RESTORATION**

METHODOLOGY: The three adjacent municipalities cooperatively purchased a floating pump with a 2 m^3/sec capacity to transfer surface water to the 10 m depth. Only winter and spring operation is anticipated in order to avoid increasing the oxygen demand of the bottom waters through the introduction of surface water with a high organic load. The cost of the pumping equipment was about $10,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The unit was placed in operation in December, 1972. Results are not available as yet. **REFERENCES**: Cronholm (pers. comm.), Engvall (pers. comm.; reports are available), Reinus (pers. comm.; internal report is available).

LAKE NAME: Grycken

LOCATION: Falu commune, Dalarna County, Sweden

SURFACE AREA: 2.5 km^2

MAXIMUM DEPTH: 15 m

PROBLEM: Absence of fish, occasional production of hydrogen sulfide. Influx of wastewaters from a pulp and papermill. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen conditions and to raise the pH. **RESTORATION METHODOLOGY**: The quantity of wastewaters was reduced by remodelling the industrial production processes; the quality was improved by treatment before release into the lake. Also, an aeration system was installed in the lake. The total cost of these measures over the last 10 yrs was about $2,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The BOD loading was reduced by over 50% and the evolution of hydrogen sulfide has ceased. The effort to restore this lake is continuing. **REFERENCES**: Lundberg (pers. comm.).

LAKE NAME: Hagelsjön

LOCATION: Dalecarlia, Sweden

SURFACE AREA: 70 ha

MAXIMUM DEPTH: 13 m

PROBLEM: Hypolimnetic oxygen deficiency, resulting in a gradually worsening fishery. **RESTORATION OBJECTIVE**: To restore the fishery and to improve the lake environment in general. **RESTORATION METHODOLOGY**: Two small hypolimnetic aeration units ("Limno") were installed to oxygenate the bottom waters without disrupting the thermal stratification. The total cost was about $19,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: One unit was installed in August, 1972 and the other in February. Operation has since been intermittent during the summer and winter. High levels of dissolved oxygen have been maintained throughout the entire lake. **REFERENCES**: Atlas Copco AB (pers. comm.).

LAKE NAME: Hornborgasjön

LOCATION: Vastergotland, Sweden

SURFACE AREA: 30 km^2

MAXIMUM DEPTH: 3 m

PROBLEM: Heavy growth of aquatic and marsh plants due to lower water levels. Lake was fast becoming a dry marsh. **RESTORATION OBJECTIVE**: To recreate an open water lake, an important area for waterfowl, by: (1) converting the macrophyte development from emergents to submergents, (2) restoring the lake bottom (now interwoven by a root felt), and (3) raising the water level by 1.0 to 1.5 m. **RESTORATION METHODOLOGY**: Reed harvesting was accomplished by means of pontoon-equipped and amphibious machines. The bottom was treated by means of amphibious rotor-cultivators and amphibious excavators. Prototype machines were constructed for this project. The water level was also raised and some of the nearby agricultural canals were filled in to increase the water supply to the lake. The total cost was about $700,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results to date have been exceedingly good with increased bottom and waterfowl fauna. Some sedge stands are expanding under present water conditions. **REFERENCES**: Björk (pers. comm.), Björk (1971, 1972a, b, c), Björk et al. (1972), Swanberg (1972).

LAKE NAME: Järlasjön

LOCATION: Nacka, Sweden

SURFACE AREA: 84 ha

MAXIMUM DEPTH: 24 m

PROBLEM: Hypolimnetic oxygen deficiencies during the summer, resulting in sediment nutrient release. Excessive algal blooms in the epilimnion. Formerly a recipient for sewage and industrial wastes. **RESTORATION OBJECTIVE**: To increase the oxygen content of the hypolimnion without mixing the cold water with the warm surface water. To make the sediments more effective in sorbing phosphorus. **RESTORATION METHODOLOGY**: A hypolimnetic aerator was designed and installed in the lake. The first aerator, a prototype, had a capacity of 35-40 m^3/min. It was subsequently replaced by a completely submerged aerator with a greater efficiency. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During the first summer of operation (1970), the prototype aerator increased the hypolimnetic oxygen concentrations from zero to 7 mg/l. Aeration also reduced phosphate and ammonia concentrations in the hypolimnion and oxidized the top sediment layer. The capacity of the redesigned aerator for increasing the oxygen concentration is 5-6 times that of the prototype, and it has the advantage of being operable during the wintertime. Large quantities of oil in the bottom sediments continue to delay the lake's recovery, and a metalimnetic oxygen minima prevents fish from entering the hypolimnion. **REFERENCES**: Atlas Copco AB (pers. comm.), Bengtsson (pers. comm.), Bengtsson et al. (1972), Björk (pers. comm.; several reports are available), Björk (1972b).

LAKE NAME: Kocktorpssjön

LOCATION: greater Stockholm area, Sweden

SURFACE AREA: 4 ha

MAXIMUM DEPTH: 6.5 m

PROBLEM: Oxygen depletion; formation of hydrogen sulfide; increasing reed growth. **RESTORATION OBJECTIVE**: To remove the sludge with its high content of nutrients and thereby deepen the lake to prevent reed growth. **RESTORATION METHODOLOGY**: The lake was treated in 1972. Following lake drainage the sludge was excavated and taken to the deposit place in an overgrown bay on a temporary road built on the bottom of the lake. Reeds were removed mechanically. The total cost was about $145,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Carlsson (pers. comm.).

LAKE NAME: Långsjön

LOCATION: near Stockholm, Sweden

SURFACE AREA: 35 ha

MAXIMUM DEPTH: 3.5 m

PROBLEM: Hypolimnetic oxygen deficit; severely restricted habitat for fish and other aquatic organisms. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen regime. **RESTORATION METHODOLOGY**: In the summer of 1959, a 500 m length of perforated plastic tubing was laid along the lake bottom. The lake was destratified using compressed air supplied from a shore-mounted compressor. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After three weeks of operation, the oxygen content of the water increased to 57% saturation and the 12° C temperature differntial between surface and bottom waters was eliminated. The system was not operated during the winter. **REFERENCES**: Water and Waste Treatment Journal (1960).

LAKE NAME: Långsjön
LOCATION: near Stockholm, Sweden
SURFACE AREA: 35 ha
MAXIMUM DEPTH: 3.5 m

PROBLEM: High content of nutrients. Algal blooms. Fishkills caused by oxygen depletion during the winter. Earlier recipient for municipal wastewater. **RESTORATION OBJECTIVE**: To limit the planktonic algal growth and to improve the dissolved oxygen conditions during the winter by reducing the phosphorus concentration. **RESTORATION METHODOLOGY**: The lake was treated with aluminum sulfate in April, 1968 and May, 1970 at a rate of 50-60 g/m^3 (approx. $4,000 USA) each time. About 33.5 tons of chemical were used. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The phosphorus concentrations were reduced only temporarily by the treatments. The 1968 application caused an 80% reduction in phosphorus levels; however, following heavy runoff in spring, 1969 the concentrations were only 40% below the original values and by May, 1970 just 25%. This increase may at least be partly due to unidentified sewage outlets. The winter dissolved oxygen conditions have improved since treatment; there has been a decrease in the number of days of anaerobosis. Although the phytoplankton volume may not have been affected, certain qualitative changes were evident. Phosphate release from the sediments have also been reduced. **REFERENCES**: Blomquist et al. (1971), Carlsson (pers. comm.), Cronholm (pers. comm.), Jernelöv (pers. comm.), Jernelöv (1970).

LAKE NAME: Lötsjön
LOCATION: greater Stockholm area, Sweden
SURFACE AREA: 6 ha
MAXIMUM DEPTH: 3 m

PROBLEM: Algal blooms; increasing reed growths; high phosphorus concentrations. **RESTORATION OBJECTIVE**: To diminish the phosphorus concentration. **RESTORATION METHODOLOGY**: The lake was treated in 1968-1970. Granulated aluminum sulfate was applied at a rate of 125 g/m^2 or 85 g/m^3. The total cost was about $19,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment had only a temporary effect because of continuing nutrient inputs from birds and stormwater inflow. The lake must be treated with Al SO_4 nearly every year to maintain improved conditions. **REFERENCES**: Carlsson (pers. comm.).

LAKE NAME: Mälaren (Steningeviken)
LOCATION: Sigtuna, Stockholm County, Sweden
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Increasing reed growth; quagmire. 0.5 m cultural sludge. Earlier recipient of municipal wastewater. **RESTORATION OBJECTIVE**: To remove the sludge from the bay (6 ha) where nutrients have accumulated. To increase the depth to more than 2 m in order to prevent reed growth. **RESTORATION METHODOLOGY**: Sludge, roots, and particles of plants that accumulated in the bay were pumped up from the bottom into sediment basins built along the shore. About 60,000 m^3 of sediments were removed from the lake. Total cost was approx. $300,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The restoration was just finished; results are not yet available. **REFERENCES**: Carlsson (pers. comm.).

LAKE NAME: Norrviken
LOCATION: central Sweden
SURFACE AREA: 2.7 km^2
MAXIMUM DEPTH: 12.2 m

PROBLEM: Strongly eutrophic due to the influx of both industrial and domestic sewage. Inflow from eutrophic Vallentunasjön. **RESTORATION OBJECTIVE**: To improve the conditions by diverting the sewage from the lake; to study the course of recovery expected to take place. **RESTORATION METHODOLOGY**: In June, 1969 the effluents were diverted from the lake by tunnel to a sewage treatment plant outside of the drainage basin. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The study emphasized P, N, and phytoplankton production; investigations were conducted before and after diversion. The estimated hydraulic residence time was 10 months. The nutrient loading was reduced from about 70 g $N/m^2/yr$ and 4 g $P/m^2/yr$ in 1961-62 to about 20 g $N/m^2/yr$ and 2 g $P/m^2/yr$ in 1970. Within two years the concentrations in the lake decreased by approximately 50% for N and 30% for P. One year after diversion the phytoplankton biomass were reduced and the water clarity increased by about 50%. Production was, however, higher in 1970. Further lake recovery was not expected unless the P loading was reduced in the future. **REFERENCES**: Ahlgren (1972, 1973).

LAKE NAME: Ösbysjön
LOCATION: Djursholm, Sweden
SURFACE AREA: 4.6 ha
MAXIMUM DEPTH: 3 m

PROBLEM: Overabundance of macrophytes, especially reeds (*Phragmites* sp.), and water milfoil *(Myriophyllum verticillatum)*, and *Nuphea alba*. Limited recreational use (bathing). **RESTORATION OBJECTIVE**: To limit the macrophyte growth by biological means. **RESTORATION METHODOLOGY**: Grass carp *(Ctenopharyndogon idellus)* were introduced during 1969-72 to feed on the macrophytes. Experiments were made during the three years with 250 two-year-old fish, 4300 one-year-old fish, and 1900 two-year-old fish. The two-year-old fish were found necessary because of natural predation. The total costs were about $20,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophyte standing crop was reduced by over 50% after one year and was eliminated completely during 1973. The dissolved oxygen content and the phosphorus levels have increased. The turbidity and phytoplankton biomass have also increased somewhat, but this may not be permanent. The results are somewhat inconclusive due to atypical climatic conditions during the study period; however, studies are continuing. **REFERENCES**: Ahling (pers. comm.), Ahling (1972), Ahling and Jernelöv (1971a and b), Carlsson (pers. comm.), Jernelöv (pers. comm.).

LAKE NAME: Råcksta träsk
LOCATION: Stockholm, Sweden
SURFACE AREA: 37 ha
MAXIMUM DEPTH: 2.5 m

PROBLEM: Dense growths of macrophytes and highly turbid water during the summer. Dissolved oxygen depletion during the winter. In the past, the lake has received storm runoff containing petroleum and other pollutants; the phosphorus concentration is high. **RESTORATION OBJECTIVE**: To improve the trophic status of the lake. **RESTORATION METHODOLOGY**: The Stockholm Department of Parks and Sports plans to begin dredging in the spring of 1973. The sediments and vegetation will be pumped to settling basins and the water will be returned to the lake after treatment with aluminum sulfate. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not available at this time. **REFERENCES**: Cronholm (pers. comm.).

LAKE NAME: Ravalen

LOCATION: Sollentuna, Sweden
SURFACE AREA: 30 ha
MAXIMUM DEPTH: 2 m

PROBLEM: Overabundance of macrophytes, especially *Stratiotes aloides* and *Typha angustifolia*. **RESTORATION OBJECTIVE**: To maintain an open water area for aesthetic, ornithological, and recreational purposes. **RESTORATION METHODOLOGY**: The water level was raised 0.5 m. Mechanical removal of submergent and emergents was undertaken at one end of the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: One year after raising the water level there was a decreased prevalence of floating macrophytes. No increase in nutrients or phytoplankton was observed. **REFERENCES**: Brammer (pers. comm.; report is in preparation).

LAKE NAME: Rönningesjön

LOCATION: greater Stockholm area, Sweden
SURFACE AREA: 69 ha
MAXIMUM DEPTH: 4.7 m

PROBLEM: Excessive algal growths; eutrophic conditions. **RESTORATION OBJECTIVE**: To reduce the plankton by using silver carp *(Hypophthalmichthys molitrix)*. **RESTORATION METHODOLOGY**: Two 50 m^2 enclosures were placed in the lake in 1973. Fish were introduced into one of these containers. The total costs were about $8400 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During the first summer the quantity of plankton was lower in the container with fish. Biological and physico-chemical analyses are continuing. **REFERENCES**: Carlsson (pers. comm.).

LAKE NAME: Södra Hörken (Grängesbergsviken)

LOCATION: Grängesberg, Sweden
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Extremely dense growth of *Cladophora* due to the influx of municipal sewage, phosphorus extracted from iron ore, and nitrogen from a factory for explosives. High content of phosphorus and nitrogen in this 15 ha, 22 m deep bay. **RESTORATION OBJECTIVE**: To reduce the growth of *Cladophora* by reduction of the phosphate content and alkalinity. **RESTORATION METHODOLOGY**: The bay was treated with granulated aluminum sulfate (total of about 160 tons) for nutrient precipitation in spring, 1971. The dry chemical was applied by "controlled dumping" in the deepest area of the bay. The granular size was regulated to achieve floc formation primarily in the hypolimnion. The treatment was complicated by the low buffer capacity of the surface waters. The total cost was approx. $15,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Based on visual observations, the growth of *Cladophora* has been effectively reduced to the present (during the first two years). The concentration of phosphorus was substantially reduced in the hypolimnion with little effect on the epilimnetic levels. **REFERENCES**: Ahling and Råghall (1973), Jernelöv (pers. comm.).

LAKE NAME: Träsksjön

LOCATION: Sweden
SURFACE AREA: 12.1 ha
MAXIMUM DEPTHH: 4 m

PROBLEM: Dissolved oxygen depletion during the winter. **RESTORATION OBJECTIVE**: To increase the dissolved oxygen content of the lake in order to prevent winterkills. **RESTORATION METHODOLOGY**: During March, 1963 two separate aeration techniques were evaluated in different areas of the lake. A gasoline-driven compressor was used to directly inject compressed air and an electrically-operated turbine was used to create a current. Both devices were operated for 48 hours. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Entirely negative results were reported with both devices. A few hours after start-up, the dissolved oxygen concentration in the areas affected by the aerators were a uniform 4 mg/l, a value which closely corresponded to the weighted mean prior to aeration. Continued aeration resulted in a decrease in the dissolved oxygen concentration due to mixing with anoxic water containing hydrogen sulfide at the mud-water interface. **REFERENCES**: Karlgren and Lindgren (1963).

LAKE NAME: Trehörningen

LOCATION: greater Stockholm area, Sweden
SURFACE AREA: 60 ha
MAXIMUM DEPTH: 3.5 m

PROBLEM: Increasing reed growth, primarily Phragmites. Algal blooms; DO depletions; generation of H_2S. Eutrophic conditions caused by the previous influx of municipal wastewaters. **RESTORATION OBJECTIVE**: To remove the cultural sludge by hydraulic dredging where nutrients have accumulated. **RESTORATION METHODOLOGY**: Reed harvesting. Sludge dredging. The sludge will be dredged and deposited in embanked bays which are now covered with reeds. The drainage water will be treated with aluminum sulfate. The reeds will be harvested mechanically. The total costs will be about $1,300,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The restoration is planned for 1973-76; results are not now available. **REFERENCES**: Carlsson (pers. comm.), Johnson (pers. comm.).

LAKE NAME: Lake Trummen

LOCATION: Växjö, Sweden
SURFACE AREA: 70 ha
MAXIMUM DEPTH: 2 m

PROBLEM: Heavy growths of algae and macrophytes. Winter oxygen depletions and fishkills; low DO's at night during the summer. Upper 40-50 cm of sediments rich in nutrients. Recipient of sewage and industrial waste until 10 years ago; subsequent natural recovery was unsatisfactory. **RESTORATION OBJECTIVE**: To remove the upper nutrient-rich sediments in order to improve the trophic status of the lake. **RESTORATION METHODOLOGY**: Dredging operations began in 1970. The upper 50 cm of lake sediments were During 1971, a cutter head was used to dredge weedy areas. Spoils were pumped to sedimentation ponds and the clarified return water was treated with aluminum sulfate to remove phosphorus. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Dredging of 600,000 m^3 of gytta has increased the lake volume by 70%. The total phosphorus concentration of the lake water in the summer of 1971 was about 100 μg/l, compared to values as high as 1000 μg/l in 1968 and 1969. Changes in Kjeldahl nitrogen, alkalinity, and pH are probably attributable to aluminum sulfate treatment of the return waters. Dissolved oxygen concentrations remained well above critical levels during the winter of 1970-1971, compared to total depletion in earlier years. In 1970-1971 green algae replaced blue-green algae to a large extent, although phytoplankton production was still high in 1970. Recolonization by macrophytes is expected due to the declining phytoplankton turbidity. Improvements in water quality (e.g., transparency, nutrient content, and productivity) have continued through the summer of 1973. **REFERENCES:**Andersson et al., 1973, Björk (pers. comm., 1972 a and b), Björk et al. (1972), Gibson (1971).

LAKE NAME: Tullingesjön

LOCATION: Stockholm, Sweden

SURFACE AREA: 1.7 km^2

MAXIMUM DEPTH: 32 m

PROBLEM: Hypolimnetic oxygen depletion; heavy algal growth; and development of hydrogen sulfide odors. Recipient of domestic wastes. **RESTORATION OBJECTIVE:** To test hypolimnetic aeration equipment which would oxygenate the bottom waters without disrupting thermal stratification. **RESTORATION METHODOLOGY:** Bottom water was air-lifted into a 100 m^3 plastic basin and then returned to the hypolimnion. The entire assembly, including compressors, was supported by floats. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The main purpose of the test was to determine design criteria. The unit was run only for a few months in 1969 and had a negligible effect on the oxygen levels in the lake due to the small capacity and the short treatment period. **REFERENCES:** Atlas Copco AB (pers. comm.), Bengtsson et al. (1972).

LAKE NAME: Uttran

LOCATION: Stockholm area, Sweden

SURFACE AREA: 2.5 km^2

MAXIMUM DEPTH: 16 m

PROBLEM: Nuisance algal blooms and hypolimnetic H_2S-production, induced by the influx of wastewater effluent. **RESTORATION OBJECTIVE:** To limit the planktonic algal growth and to improve the dissolved oxygen conditions by reducing the phosphorus concentration. **RESTORATION METHODOLOGY:** In 1968 reduction of the phosphorus loading was achieved by chemical treatment of the sewage (Al-flocculation). Total diversion is planned to start within a few years and should be complete by 1975. The running cost in 1968-1969 was about $12,000 USA/year. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The P levels in the lake were reduced from a weighted mean value of approx. 200 μg/l to approx 60 μg/l. Until now no significant or systematic changes in plankton biomass, water transparency, or winter oxygen levels have been observed, although there has been an apparent change in phytoplankton species composition. **REFERENCES:** Karlgren (pers. comm.).

LAKE NAME: Växjösjön

LOCATION: Växjö, Sweden

SURFACE AREA: 87 ha

MAXIMUM DEPTH: 6.5 m

PROBLEM: Heavy algal growth and oxygen depletion in the bottom waters during the summer. Winterkill of fish has also been a problem. **RESTORATION OBJECTIVE:** To test the design and effectiveness of a lake aeration system. **RESTORATION METHODOLOGY:** A shore-mounted compressor was used to supply a net of perforated air lines totalling 2.4 km in total length. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The aeration system was operated during two summers and the intervening winter. The results were used to develop design criteria for future projects. **REFERENCES:** Atlas Copco AB (pers. comm.), Bengtsson et al. (1972).

LAKE NAME: Three (3) lakes

Lake of Biel

Lake of Brienz

Lake of Thun

LOCATION: Canton Bern, Switzerland

SURFACE AREA / MAXIMUM DEPTH:

Lake of Biel (39 km^2) / 74 m

Lake of Brienz (30 km^2) / 261 m

Lake of Thun (48 km^2) / 217 m

The Aare River flows from Brienz to Thun to Biel

PROBLEM: Eutrophication. The Lake of Biel is moderately eutrophic and the other two, mesotrophic. Oxygen deficiency below 50 m in late summer. **RESTORATION OBJECTIVE:** To reduce the inflow of phosphorus. **RESTORATION METHODOLOGY:** Phosphorus elimination will be implemented at all of the sewage treatment works in the drainage area of each lake by 1976 (Government resolution of March, 1971). In addition, a diversion canal will be constructed partly around the Lake of Thun; after treatment of the wastewater, the effluent will be released into the river between the Lake of Thun and the Lake of Biel. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Results are not available as yet. **REFERENCES:** Nef (pers. comm.)

LAKE NAME: Lake Bret

LOCATION: Lausanne, Switzerland

SURFACE AREA: 50 ha

MAXIMUM DEPTH: 20 m

PROBLEM: Hypolimnetic oxygen depletion and high iron and carbon dioxide concentrations during the summer. Used as a municipal water supply. **RESTORATION OBJECTIVE:** To improve the water quality. **RESTORATION METHODOLOGY:** An aeration plant was constructed on the shore to improve hypolimnetic oxygen concentrations without disrupting thermal stratification. Water was pumped from the 13.5 m level to the plant, aerated, and then discharged back into the lake at the 13.5 m depth at a distance of 178 m from the intake. The discharge was located about 50 m away from the municipal water supply intake. Operations occurred for 4.5 months/year since 1947. 10,000 m^3 of water were pumped through the aerator every 24 hours and a large fan, rated at 20 m^3/min, produced a continuous air current through the aeration chamber. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Comparing an aeration year, 1951, to the 1943 control year, hypolimnetic aeration produced a slight increase in bottom temperatures of 1° to 2° C, and the temperatures in the hypolimnion were more uniform. Aeration did not result in a dramatic increase in dissolved oxygen concentrations in the hypolimnion; during both 1943 and 1951 dissolved oxygen concentrations at the bottom approached zero. However, a 1-2 mg/l increase in dissolved oxygen concentrations was observed at the 12 and 14 m depths. Dissolved oxygen concentrations at these depths were slightly higher than the concentrations at 8 and 10 m on several occasions, indicating a positive effect of aeration. Based on the difference in the concentrations in the incoming and discharging water, about 9,500 kg of oxygen were added to the hypolimnion and 8,500 kg of carbon dioxide were removed during the 4-½ month aeration period in 1951. An increase in pH in the hypolimnion (maximum of 0.6 units) was attributed to the elimination of CO_2. Aeration also effectively oxidized the iron. **REFERENCES**: Mercier and Gay (1954), Mercier and Perret (1949).

LAKE NAME: Lake Hallwil

LOCATION: Canton Aargau/Luzern, Switzerland
SURFACE AREA: 10.3 km^2
MAXIMUM DEPTH: 48 m

PROBLEM: Eutrophic conditions; no oxygen near the bottom. **RESTORATION OBJECTIVE**: To reduce the nutrient influx to the lake. **RESTORATION METHODOLOGY**: A diversion channel is being constructed around most of the lake to take up the raw sewage and transport it to a biological treatment plant. The effluent will discharge into the Lake Hallwil outflow. However, the stream flowing into the lake comes from eutrophic Lake Baldegg and this will not be affected. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not available. **REFERENCES**: Ambühl (1960), Schmid (pers. comm.).

LAKE NAME: Lake of Inkwil

LOCATION: Cantons Bern and Solothurn, Switzerland
SURFACE AREA: 12 ha
MAXIMUM DEPTH: 8 m (mean depth, 2.7 m)

PROBLEM: Fishkills caused by oxygen depletion in midsummer; about 3/4 of the lake is covered with water lily *(Nymphaea)* by the end of the summer. **RESTORATION OBJECTIVE**: To reduce the influx of primary and secondary treated wastewaters; to correct some of the eutrophication-related problems. **RESTORATION METHODOLOGY**: Wastewaters (exclusive of drainage waters) were diverted in late 1969. Water lilies have been cut and removed for several years. High quality drinking water has been introduced into the deepest region of the lake during the summer since spring, 1970. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Oxygen conditions have improved, preventing fishkills. No change has been noted in the phytoplankton development. **REFERENCES**: Nef (pers. comm.).

LAKE NAME: Mauensee

LOCATION: near Sursee, Switzerland
SURFACE AREA: 51 ha
MAXIMUM DEPTH: 7.0 m

PROBLEM: Algal blooms; oxygen depletion. Eutrophic conditions induced by agricultural and household wastes, including laundry wastes. Agricultural phosphorus input alone is sufficient to produce eutrophic conditions. **RESTORATION OBJECTIVE**: To re-establish less eutrophic conditions by reducing the phosphorus concentration. **RESTORATION METHODOLOGY**: Water has been discharged from the deepest area of the lake via a plastic pipe since 1968. A limnological survey was conducted during the experiment. More sewer systems were constructed in the surrounding area. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A decrease in P– and N-concentration and increase in oxygen levels have been observed, but the cause is not yet certain. A new series of observations will begin in spring 1973. **REFERENCES**: Gächter (pers. comm.; internal reports are available).

LAKE NAME: Pfaffikersee

LOCATION: Zurich, Switzerland
SURFACE AREA: 3.3 km^2
MAXIMUM DEPTH: 35 m

PROBLEM: Highly eutrophic; hypolimnetic oxygen depletion; high hydrogen sulfide concentrations; and blue-green algal blooms. Used for industrial water supply. **RESTORATION OBJECTIVE**: To improve hypolimnetic dissolved oxygen concentrations in order to provide a dependable year-round supply of high quality water. **RESTORATION METHODOLOGY**: The lake was aerated during 1958-63. The aeration system consisted of a vertical 2 m diameter pipe supported by floats extending from a depth of 28 m to the surface. Air was supplied from a shore-mounted compressor and was introduced at the base of the pipe through a diffuser. Water was airlifted through the system at a rate of about 6 m^3/sec continuously from the beginning of stratification in April/May to September. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Operation of the aerator did not lead to complete destratification, but caused autumnal overturn to take place about one month earlier than usual. However, the rate of hypolimnetic oxygen depletion at the onset of stratification was retarded and the anaerobic period during the summer was shortened. Hypolimnetic hydrogen sulfide and ammonia concentrations were reduced during aeration, but nitrate nitrogen concentrations increased. Prolific and repeated algal blooms resulted from the fertilizing effect of the mixing process, and the blue-green algae *Aphanizomenon flos-aquae* appeared in bloom proportions for the first time in 1961. Salmonid populations were greatly reduced because of the warming of the lower levels of the lake. The increased temperature was also undesirable from a water supply standpoint. The project was terminated in 1962 because of the general deleterious effects. **REFERENCES**: Ambühl (1962, 1967), Thomas (1966).

LAKE NAME: Rotsee

LOCATION: near Lucerne, Switzerland
SURFACE AREA: 47 ha
MAXIMUM DEPTH: 16.3 m

PROBLEM: Eutrophication caused by the inflow of poorly or untreated sewage, nutrient-rich agricultural runoff, and enriched groundwater. Massive blooms of *Oscillatoria rubescens* first appeared about 1910 and has been followed by *Anabaena catenula/affinis*. **RESTORATION OBJECTIVE**: To prevent further eutrophication by flushing and sewage diversion. Reversal of the process was not expected due to the low rate of water replacement and the continued nutrient input from other sources. **RESTORATION METHODOLOGY**: Flushing began in 1922 with water from a nearby creek (0.5 m^3/sec). The approximate cost of the canal was $1,500,000 USA. Collection and diversion of the sewage began in 1933. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Highly eutrophic conditions still prevailed during 1945. *Oscillatoria rubescens* dominated the phytoplankton. In May **DO** was absent below 12.5 m, with a sulfide concentration of 3.6 mg/l at 15 m. In October, **DO** was absent at 7.5 m and the level of sulfide was 4.7 mg/l at 10 m. **REFERENCES**: Minder (1948).

LAKE NAME: Wilersee

LOCATION: near Zurich, Switzerland
SURFACE AREA: 3.2 ha
MAXIMUM DEPTH: 20.5 m

PROBLEM: Creeping eutrophication stemming from urbanization and agriculture. In 1961 no DO was present below 3 m, and 5 mg/l PO_4, 1.5 mg/l Fe, 0.5 mg/l Mn, and H_2S occurred in the hypolimnion. Nuisance blooms of *Asterionella formosa* and *Synedra* developed in the epilimnion. **RESTORATION OBJECTIVE**: To check and reverse the increasing water quality deterioration. **RESTORATION METHODOLOGY**: A ring canal was constructed for the collection and treatment of domestic and agricultural wastewaters. Also, waters were discharged from the hypolimnion (similar to the technique used at Kortowosee, Poland). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In 1966, five years after the restoration techniques were implemented, the lake became suitable for contact recreation. The water clarity increased to 1.86 m (20 cm in 1961); the pH dropped to 8.5 (10.4 in 1961); DO was present to 14 m; there was only a trace of P/liter; H_2S was present below 20 m (3 m in 1961); the concentration of Fe became less than 0.5 mg/l; and the levels of Mn dropped below detectable limits. **REFERENCES**: Eschmann (1969).

LAKE NAME: Zürichsee
LOCATION: Switzerland
SURFACE AREA: 88 km^2
MAXIMUM DEPTH: 138 m

PROBLEM: Nuisance algal blooms. Oxygen depletion in the bottom waters. Eutrophic conditions induced by water pollution (150,000 inhabitants). Degradation of water supply, fisheries, and general recreation. **RESTORATION OBJECTIVE**: To limit the algal growth. To improve the dissolved oxygen conditions. To stop and, at least to some degree, reverse the trend toward eutrophication. **RESTORATION METHODOLOGY**: The sewages are treated by the activated sludge procedure, and simultaneous phosphate elimination with ferric chloride. The purified sewage is discharged into the 3-6 m upper boundary of the thermocline. Improved sewage treatment facilities were installed in the years 1967-1970. About 90% of the P is removed from the sewage by the treatment procedure. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There has been a decrease in phosphorus concentration in the lake water. Nuisance planktonic algal blooms were eliminated. Dissolved oxygen concentrations in the hypolimnion were increased. No adverse ecological consequences were observed. Significant changes began to occur before all of the treatment facilities were completed, and especially since 1967. **REFERENCES**: Thomas (1971), Thomas and Rai (1970), Wildi (1972).

LAKE NAME: Lake of Tunis (north side)
LOCATION: Tunis, Tunisia
SURFACE AREA: 29.5 km^2
MAXIMUM DEPTH: ---

PROBLEM: Influx of domestic and industrial wastewaters, including raw sewage. Accumulation of sludge deposits in some areas. Generation of obnoxious odors. Excessive algal growths, especially sea lettuce *(Ulva)*. Unaesthetic conditions. **RESTORATION OBJECTIVE**: To eliminate the major existing problems. To halt, and eventually reverse, the trend toward progressively worsening conditions. **RESTORATION METHODOLOGY**: The proposal includes: (1) dredging of sludge deposits (laboratory tests indicate that the sediments release 500-900 and 25-30 mg/m^2/day of NH_4-N and PO_4-P, respectively to the overlying waters) with treatment of the return waters for nutrient removal, (2) ponding and/or aeration of the areas now subject to sewage inflow, (3) construction of an advanced wastewater treatment plant with diversion of the effluent from the lake, (4) mechanical harvesting of the algae (and therefore the nutrients), and (5) modifications in the hydrodynamics of the system in order to increase nutrient flushing from the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Preliminary studies are now underway. Full-scale activities are scheduled to begin in November, 1973. **REFERENCES**: Björk (pers. comm.), Björk (1972b).

LAKE NAME: One (1) lake
LOCATION: Chesterford Park Research Station, United Kingdom
SURFACE AREA: 8100 m^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of macrophytes. **RESTORATION OBJECTIVE**: To develop and use effective herbicides. **RESTORATION METHODOLOGY**: About 2000 m^2 was treated with simazine in the wettable powder formulation on 31 August. The herbicide was applied to the surface, yielding a concentration of 6 mg/l in the treated area (0.25 mg/l for the whole lake). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The entire lake became virtually clear of vegetation except perhaps in the deep areas. All of the submerged vegetation except *Chara* and *Vaucheria* were severely reduced or eliminated within six weeks. In July of the following year only *Chara* was present. Two years after treatment some *Myriophyllum* spp. were noted in the untreated area and filamentous algae was growing on the bottom. The concentration of simazine became extremely low, almost undetectable, within one year; the flow of water through this lake was insignificant. **REFERENCES**: Whitaker (1967).

LAKE NAME: One (1) reservoir
LOCATION: Barry, Glamorgan, United Kingdom
SURFACE AREA: 9 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of macrophytes. **RESTORATION OBJECTIVE**: To determine the effects of herbicide treatment (paraquat) on reservoir ecology. **RESTORATION METHODOLOGY**: Esgram (200 g active ingredient paraquat/l) was applied to the reservoir from a boat using a hand-operated sprayer. The first application, on 14 June, 1971, gave a concentration within the reservoir of 1 mg/l and the second application, on 29 July, 1971, a concentration of 0.6 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Successful control was achieved by the first application, especially for *Potamogeton pectinatus* and *Myriophyllum spicatum*. The second application failed to control regrowth of *Chara globularis*. Although gross deoxygenation did not occur after treatment, there was a definite change in the oxygen content of the water. Paraquat was quickly lost from the water after each application and was largely taken up by the sediments, never more than 6% of the initial dose being recorded from the macrophytes. Final analysis of the sediments indicated that about 36% of the total amount of paraquat applied to the reservoir was not recovered. **REFERENCES**: Brooker and Edwards (1973).

LAKE NAME: One (1) pond
LOCATION: Kent, England, United Kingdom
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of *Elodea canadensis*. **RESTORATION OBJECTIVE**: To eliminate the macrophytes. **RESTORATION METHODOLOGY**: Grass carp *(Ctenopharyn-*

godon idella) were stocked as a possible biological control agent. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The macrophytes were successfully eliminated from the pond. **REFERENCES:** Nature (1968).

LAKE NAME: Five (5) lakes
LOCATION: England, United Kingdom
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of algae and macrophytes. **RESTORATION OBJECTIVE**: To study the effects of paraquat on several species of submergent and floating plants and two genera of filamentous algae. **RESTORATION METHODOLOGY**: Gramoxone JF 1341 (containing 20% paraquat and 0.09% of a wetting agent) was applied in May, 1965 to give a nominal concentration of 0.5 mg paraquat/l. The chemical was applied evenly from a boat using a watering can with an ordinary "garden hose" attachment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: All submerged and floating plants (i.e., *Elodea canadensis, Myriophyllum spicatum, Potamogeton crispus, P. pectinatus*), except *Polygonum amphibium* and *Chara*, were eliminated within 32 days of application. One lake remained substantially free of vegetation for two years after treatment. No mats of filamentous algae developed in the treated lakes, although algal mats were widespread in adjacent untreated lakes. Bacteria populations increased after treatment; invertebrates did not appear to be affected. Paraquat disappeared rapidly from the water. Significant quantities of the chemical were found in the weeds within 24 hours of application. There was a gradual buildup of paraquat residues in the bottom deposits for about one year followed by a sharp decrease. **REFERENCES**: Way et al. (1971).

LAKE NAME: Six (6) ponds
LOCATION: England, United Kingdom
SURFACE AREA: 250 m^2 each
MAXIMUM DEPTH: 0.8 m each

PROBLEM: Overabundant growth of submerged macrophytes, especially *Myriophyllum verticillatum, Callitriche* sp., and *Potamogeton pectinatus.* **RESTORATION OBJECTIVE**: To control the macrophyte growths. To develop a control method alternative to mechanical harvesting and herbicide treatment. **RESTORATION METHODOLOGY**: Grass carp *(Ctenopharyngodon idella* Val.*)* were stocked in May, 1968 at rates ranging from 238 to 959 kg/ha. Three additional ponds were used as controls. The mean weight of the fish was 168 g. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: By September, 1968, submergents had completely disappeared from the most heavily stocked pond. The results indicated that stocking rates of about 200,350, and 600 kg/ha would provide 25, 50, and 75% reduction in macrophyte biomass in mid-summer. The fish preferred some macrophyte species over others. **REFERENCES**: Stott and Robson (1970), Stott et al. (1971).

LAKE NAME: Blelham Tarn
LOCATION: United Kingdom
SURFACE AREA: 11 ha
MAXIMUM DEPTH: 13.4 m

PROBLEM: Hypolimnetic oxygen depletion following strong thermal stratification during the summer. This lake is essentially a field laboratory of the Freshwater Biological Association and has been carefully monitored since 1948. **RESTORATION OBJECTIVE**: To assess the effects of destratification and aeration on the physical and biological parameters. **RESTORATION METHODOLOGY**: Five "Aero-Hydraulic Guns" were installed in two separate deep holes in the lake. The rate of water flow through the guns was restricted to a total of 12,600 m^3/day in order to spread the destratification over a period of days and allow careful observation. Operations began 31 July, 1961, and ended 28 August. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Prior to aeration the lake was strongly stratified, and dissolved oxygen was absent below a depth of 7 m. After 14 days, the lake was destratified, and the top to bottom temperature differential was less than 1° C. Dissolved oxygen decreased slightly at the surface, from 9.5 to 7.5 mg/l, but increased to about 5.5 mg/l at the bottom. Iron concentrations in the bottom waters fell from 4 mg/l to zero. Phosphorus and manganese concentrations exhibited similar patterns. Mixing did not cause any changes in the crops of algae, but their distribution in depth was altered. The lake restratified when the aerators were shut down and the observed chemical changes in the bottom waters were short-lived. **REFERENCES**: Bryan (1964), Gilson (1962), New Zealand Outdoor (1965).

LAKE NAME: Chew Valley Lake
LOCATION: North Somerset, United Kingdom
SURFACE AREA: 4.9 km^2
MAXIMUM DEPTH: 11.5 m

PROBLEM: Hypolimnetic dissolved oxygen depletion during the summer; nuisance algal growths. Used as a municipal water supply. **RESTORATION OBJECTIVE**: To reduce algal growths and improve the dissolved oxygen regime. **RESTORATION METHODOLOGY**: Agricultural pollution will be controlled by storage and land disposal of wastes. Summer destratification of the lake is also planned. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The proposed action will commence in 1973. **REFERENCES**: Griffiths (pers. comm.), Wilson (pers. comm.).

LAKE NAME: Eglwys Nungdd
LOCATION: Glamorgan, Wales, United Kingdom
SURFACE AREA: 1 km^2
MAXIMUM DEPTH: 3.5 m

PROBLEM: Obnoxious blue-green algal blooms. **RESTORATION OBJECTIVE**: To demonstrate a method of collapsing the gas vacuoles in blue-green algae thereby causing them to sink. **RESTORATION METHODOLOGY**: Lengths of 20 m of a pentaerythritol tetranitrate based fuse were rolled into small balls and used as point charges. Line charges were of the same materials and were used in lengths of 150 m. Both point charges and line charges were suspended at the 1.5 m depth. The explosion had to create a minimum pressure peak of 4.5 Rg cm^{-2} in order to collapse the gas vacuoles. The cost was approximately $8.50 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The technique can be used effectively, although there are deleterious side effects on other members of the community (i.e., fish). **REFERENCES**: Edwards (pers. comm.; several reports are in preparation), Menday and Buck (1972).

LAKE NAME: Farmoor Reservoir
LOCATION: Oxfordshire, England, United Kingdom
SURFACE AREA: 49 ha
MAXIMUM DEPTH: 11 m

PROBLEM: Hypolimnetic dissolved oxygen depletion and high iron and manganese concentrations. Used as a pumped storage water supply reservoir. **RESTORATION OBJECTIVE**: To eliminate the dissolved oxygen depletions and to reduce the iron and manganese concentrations. **RESTORATION METHODOLOGY**: A jet inlet was installed in the reservoir to induce circulation and prevent stratification. Modification of the previous inlet produced a satisfactory design at a cost of about $1200 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The jet inlet was installed in late 1972, and results are not yet available. **REFERENCES**: Collingwood (pers. comm.).

LAKE NAME: King George VI Reservoir
LOCATION: England, United Kingdom
SURFACE AREA: 1.4 km^2
MAXIMUM DEPTH: 16 m

PROBLEM: Hypolimnetic oxygen depletion with high concentrations of hydrogen sulfide and ammonia. Dense crops of algae in the upper waters. Used for municipal water supply. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen levels in the bottom waters and to decrease algal concentrations. **RESTORATION METHODOLOGY**: Two axial flow floating pumps were used to control or eliminate stratification in the reservoir. Pump inlet depth was adjusted from 11 to 14 m, and the discharge pipe terminated at the surface. Each 46 cm pump was powered by an electric motor and could transfer up to 2.1 m^3/sec of water. At maximum load, the operating cost for both pumps was about $7.00 USA/day. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: At the maximum pumping rate, the thermocline was lowered at a rate of 12.7 cm/day. The thickness of the thermocline was reduced, but the thermal stability of the entire water mass increased, reducing the possibility of catastrophic overturn due to high winds. During a test period in 1966, artificial circulation increased the amount of suspended material in the epilimnion. The average concentration of algae in the deepened epilimnion decreased, but the concentration of *Anabaena* increased, posing potential water quality control problems. **REFERENCES**: Cooley et al. (1967), Ridley (pers. comm.; many publications are available), Ridley (1970), Ridley et al. (1966), Taylor (pers. comm.; many publications are available).

LAKE NAME: Lough Neagh
LOCATION: Northern Ireland, United Kingdom
SURFACE AREA: 367 km^2
MAXIMUM DEPTH: 34 m

PROBLEM: Advancing eutrophication. Nuisance blue-green algal blooms at the surface causing problems for water supply uses. Hypolimnetic oxygen depletion endangering the fishing industry. **RESTORATION OBJECTIVE**: To reduce the eutrophication-related problems by controlling the phosphorus input. **RESTORATION METHODOLOGY**: There is a proposal to **RESTORATION METHODOLOGY**: There is a proposal to reduce the phosphorus output from seven major sewage treatment plants, thereby roughly halving the present input to the lake. A pilot scheme of tertiary treatment is being tested at the largest sewage works. The total cost is estimated at about $6,600,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A variety of physico-chemical and biological parameters are under investigation, including the estimation of a nutrient budget. The total phosphorus loading is now about 300 tons/year; tertiary treatment at just seven of the sewage works is expected to reduce the phosphorus input from sewage from 256 to 89 tons/year. The lake has a mean depth of 8.6 m. **REFERENCES**: Smith (pers. comm.), Wood (pers. comm.), Wood and Gibson (1972).

LAKE NAME: Queen Elizabeth II Reservoir
LOCATION: England, United Kingdom
SURFACE AREA: 1.3 km^2
MAXIMUM DEPTH: 17.5 m (full pool)

PROBLEM: Dense algal growths in the epilimnion and hypolimnetic oxygen depletion, resulting in water treatment problems. Used as a pumped storage water supply reservoir. **RESTORATION OBJECTIVE**: To improve the water quality by mixing and aeration. **RESTORATION METHODOLOGY**: A destratification system was designed to take advantage of the continuous inflow and outflow of the reservoir. Eleven inlet jets were placed on the bottom; nine high velocity jets were designed to discharge from the horizontal, and two low-velocity jets discharged water vertically. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Destratification effectively controlled biochemical deterioration of water quality in the bottom waters and increased the filterability of the water. In practice, the use of only the 22 ½ degree jets was usually sufficient to maintain isothermal conditions at a total discharge rate of about 110,000 m^3/day, which was less than 1% of the total reservoir volume. However, on occasions of turbid inflow or algal die-offs, particulate matter which would normally settle to the bottom of the reservoir, was kept in suspension due to the increase in turbulence, and increased numbers of algae and organic detritus, with associated bacteria, occurred in the outflow. **REFERENCES**: Cooley et al. (1967), Evans (pers. comm.), Ridley (pers. comm.; many publications are available), Ridley (1970), Ridley et al. (1966), Taylor (pers. comm.; many publications are available).

LAKE NAME: Woburn Park Estate pond
LOCATION: Wales, United Kingdom
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of *Elodea canadensis* and *Myriophyllum* spp. **RESTORATION OBJECTIVE**: To control the macrophytes. **RESTORATION METHODOLOGY**: Grass carp *(Ctenopharyngodon idella)* were introduced as a possible biological control agent. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were eliminated within six months. **REFERENCES**: Ministry of Agriculture, Fisheries and Food, England and Wales (1968).

LAKE NAME: Wraysbury Reservoir
LOCATION: England, United Kingdom
SURFACE AREA: 1.5 km^2
MAXIMUM DEPTH: 21 m

PROBLEM: Oxygen depletions with high concentrations of ammonia and hydrogen sulfide in the hypolimnion and dense growths of algae in the epilimnion. **RESTORATION OBJECTIVE**: To prevent water quality problems from occurring in this newly formed water supply reservoir. **RESTORATION METHODOLOGY**: A jet-inlet destratification system was designed for the reservoir. Six inlets, capable of introducing a maximum of 10.6 m^3/sec of river water were placed 1.5 m above the reservoir floor. The angle of the inlets varied from zero to 45 degrees above the horizontal. Two additional low-velocity inlets were used to minimize turbulence during periods of turbid inflow, and three submersible pumps were used to circulate and destratify the reservoir during periods of low inflow. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Oxygenated conditions have been maintained in the bottom waters. Seasonal succession of phytoplankton still occurs, but the population densities are usually moderate. Water treatment costs were reduced. **REFERENCES**: Cooley

(1970), Evans (pers. comm.), McGill (1969), Ridley (pers. comm.; publications are available), Ridley (1970, 1972), Taylor (pers. comm.; publications are available.

LAKE NAME: Several lakes
LOCATION: USSR
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Severe degradation; poor water quality. **RESTORATION OBJECTIVE**: To improve the water quality and inhibit oxygen depletion. **RESTORATION METHODOLOGY**: Industrial wastes–fused slag (58%, CaO; 10%; MgO; 23%, SiO_2; 10%, CaF_2; 4%, Al_2O_3; and 1% Fe_2O_3) and peat ash wastes–were added to the polluted lakes. Fused slag was applied at a concentration of about 250 mg/l and peat ash wastes at about 500 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The water quality was improved greatly with an increase in pH and a decrease in free H_2CO_3, NH_4+, and Fe content. Hydrogen sulfide was eliminated. Treatment prior to the period of ice-cover inhibited oxygen depletion during the remainder of the winter. **REFERENCES**: Balabanova (1970).

LAKE NAME: One (1) lake
LOCATION: part of the Kara Kum Canal, USSR
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Heavy growths of *Myriophyllum spicatum*, providing habitat for the larvae of blood sucking mosquitoes. **RESTORATION OBJECTIVE**: To remove the macrophytes thereby controlling the mosquito larvae population. **RESTORATION METHODOLOGY**: Grass carp *(Ctenopharyngodon idella)* were stocked into a 1.8 ha test area in 1961. The wet biomass of macrophytes was 12.5 tons/ha and the fish were introduced at the rate of 30.6 kg/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were completely eliminated. During 1962, after drainage and grass carp removal the previous winter, the macrophytes were not a problem. However, in 1963 dense macrophyte growths were again present. **REFERENCES**: Aliyev and Bessmertnaya (1968).

LAKE NAME: One (1) reservoir
LOCATION: near Moscow, Noginskii Region, USSR
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Macrophytes interfering with hydroelectric power generation. **RESTORATION OBJECTIVE**: To remove the macrophytes. **RESTORATION METHODOLOGY**: Grass carp *(Ctenopharyngodon idella)* were introduced as a possible biological control agent. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were eliminated within various areas in anywhere from two months to two years. Approximately 50 to 100 fish were sufficient to keep 1 ha macrophyte-free. Mosquito problems were also reduced. **REFERENCES**: Nikolskii et al. (1968).

LAKE NAME: Lake Beloye
LOCATION: near Moscow, USSR
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Low DO conditions due to excessive eutrophication. **RESTORATION OBJECTIVE**: To alleviate the DO problems during the winter. **RESTORATION METHODOLOGY**: An artificial aeration/circulation system was installed in the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Forced aeration disrupted the vertical density gradient, halted the formation of hydrogen sulfide, and maintained an ice-free area. Carry-over effects of winter aeration were not observed the subsequent summer. **REFERENCES**: Rossolimo and Shil'krot (1971).

LAKE NAME: Two (2) lakes
LOCATION: Bavaria, West Germany

	Surface Area	Maximum Depth	Hydr. Res. Time
Ammersee	4.7 km^2	– (mean depth 37.8 m)	2.5 yrs
Staffelsee	7.7 km^2	– (mean depth 9.7 m)	0.9 yrs

PROBLEM: Rapid algal growth; decrease of dissolved oxygen in the hypolimnion; advancing eutrophication caused by nutrient influx from untreated municipal sewage and liquid manure; hygienic problem for swimming. **RESTORATION OBJECTIVE**: To limit the algal growth and to stop further eutrophication of the lake. To improve the hygienic conditions. **RESTORATION METHODOLOGY**: A main sewer line was built around the lake. The sewage is collected, transported to a two stage treatment plant, and discharged into the lake outflow. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The algal growth has been reduced and the oxygen conditions in the hypolimnion have improved considerably. The water quality is now suitable for contact recreation. **REFERENCES**: Bucksteeg (pers. comm.), Hamm (1968), Oberste Baubehörde in Bayerischen Staatsministerium des Innern (1971).

LAKE NAME: Two (2) lakes
Möllnersee
Wittensee
LOCATION: Slesvig-Holstein, West Germany
SURFACE AREA:---
MAXIMUM DEPTH:---

PROBLEM: Eutrophic conditions. **RESTORATION OBJECTIVE**: To "rejuvenate" the lakes by covering the bottom sediments, thereby reducing their contribution to the eutrophic conditions. **RESTORATION METHODOLOGY**: Sandy materials dredged from nearby waters were distributed over the organic sludge. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Experimental controls did not exist and therefore documented results are not available. **REFERENCES**: Müller (pers. comm.).

LAKE NAME: Four (4) lakes
LOCATION: Bavaria, West Germany

Kochelsee	5.9 km^2	66.2 m	31.3 m	0.12 yrs
Pilsensee	1.9 km^2	16.0 m	9.3 m	1.1 yrs
Riegsee	1.9 km^2	-	5.3 m	1.0 yrs
Worthsee	4.4 km^2	33.0 m	13.6 m	7.1 yrs

PROBLEM: Advancing eutrophication. Influx of wastewaters. **RESTORATION OBJECTIVE**: To retard and perhaps reverse the deterioration of water quality. **RESTORATION METHODOLOGY**: Wastewaters were collected from the surrounding shorelands, treated, and discharged downstream from each lake. In some of these projects storm waters were included and advanced wastewater treatment plants were planned for rural areas within the drainage basin. Construction began in the mid-1960's. Costs were expected to range from about $1,500,000 to $42,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The publications did not contain any specific water quality data; however, it was implied that eutrophication had been slowed. **REFERENCES**: Hamm (1968), Oberste Baubehörde im Bayerischen Staatsministerium des Innern (1971).

LAKE NAME: Bodensee

LOCATION: Austria, Switzerland and West Germany

SURFACE AREA: 586 km^2

MAXIMUM DEPTH: 253 m

PROBLEM: Development of eutrophic conditions. Increased nutrients; algal blooms; low dissolved oxygen; abundant macrophytes; and decreased area of reeds. **RESTORATION OBJECTIVE**: To reduce the inflow of unpurified wastewaters, especially the phosphorus content. To limit further degradation of the lake. **RESTORATION METHODOLOGY**: Restoration measures will include: (1) collection of sewage from all surrounding shoreland communities and/or P removal at existing sewage treatment plants, (2) tighter controls and regulation of industrial wastes, (3) construction of new treatment plants, and (4) collection and treatment of storm waters. The wastewater effluents will be released into deep water only. The programs were begun or recommended in 1967 and completion is expected by 1977. The effort is being coordinated by the Internationale Gewässerschutzkommission für den Bodensee. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Various chemical and biological parameters are being investigated. No definite change in lake conditions have been observed as yet; it is expected to take many years before improvement will be noticeable. **REFERENCES**: Deutsche Forschungsgemeinschaft (1968), Einsle (pers. comm.; many publications are available from the Internat. Gewässerschutzkommission für den Bodensee), Liebmann (1965a), Oberste Baubehörde im Bayerischen Staatsministerium des Innern (1971), Schröder (pers. comm.), Schröder (1973).

LAKE NAME: Chiemsee

LOCATION: Bavaria, West Germany

SURFACE AREA: 80 km^2

MAXIMUM DEPTH: ---(mean depth, 24.5 m)

PROBLEM: Influx of domestic wastewaters directly or via rivers; high nutrient content in the Ache River, the main inflow. Nuisance algal and macrophyte growths; sludge formation in some parts of the lake. This lake is the largest totally within Bavarian borders. **RESTORATION OBJECTIVE**: To keep the present water quality (now mesotrophic). To prevent hygienic problems and preserve the high recreational value of the lake. **RESTORATION METHODOLOGY**: Three treatment plants were built for phosphorus removal by precipitation with aluminum sulfate (total P = 0.5 - 1.0 mg/l); chlorination occurs at one plant. Construction of biological treatment plants are underway at the major inflow to the lake. The total cost will be about $26,600,000 USA. The effluent will be discharged far away from the shoreline. Alterations began in 1961. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: So far there has not been a clear indication of improvement or deterioration in water quality in the specific areas concerned. The mean depth and the hydraulic residence time are 24.5 m and 1.3 yrs, respectively. Formation of anaerobic sludge deposits after introduction of the flocculated plant effluents have created some local problems. **REFERENCES**: Bucksteeg (pers. comm.), Huber (pers. comm.), Oberste Baubehörde im Bayerischen Staatsministerium des Innern (1971).

LAKE NAME: Dümmer See

LOCATION: 100 km west of Hannover, Niedersachsen, West Germany

SURFACE AREA: 12 km^2 (diked in area, 16 km^2)

MAXIMUM DEPTH: 1.5 m (mean depth, 1.1 m)

PROBLEM: Eutrophication due to the influx of domestic, industrial, and poultry-farm wastewaters. Algal blooms; vanishing submergents (*Chara*, etc.); reduction of emergents (*Scirpus*, Phragmites); and undesirable changes in the fish and waterfowl populations. Phosphate concentrations up to 2 mg/l. The lake is used for recreation and especially for the storage of flood waters. **RESTORATION OBJECTIVE**: To reduce the algal blooms in the lake, and to reduce the sediment input by the Hunte River. **RESTORATION METHODOLOGY**: Domestic sewage is now collected from the adjacent communities and taken via pipeline to a new treatment plant downstream from the lake. Further proposed projects include: (1) phosphate-elimination in all sewage treatment plants within the drainage basin of the upper Hunte River, (2) construction of an artificial sedimentation basin in the Hunte River upstream from the lake, and (3) pumping off the black sludge (500,000–700,000 m^3) from the lake bottom in order to reduce nutrient recycling. The estimated cost is $1,000,000–1,500,000 USA, including acquisition of the spoils areas. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Dahms (pers. comm.), Inst. f. Siedlungswasserwirtschaft, Technische Univ. Hannover (1970), Niedersächsisches, Landesamt f. Bodenforschung (1972).

LAKE NAME: Grebiner See

LOCATION: Plön, West Germany

SURFACE AREA: 50 ha

MAXIMUM DEPTH: 25 m

PROBLEM: Hypolimnetic oxygen depletion. Eutrophic conditions induced by agricultural erosion only. **RESTORATION OBJECTIVE**: To limit the planktonic algal growth and to improve the dissolved oxygen conditions by reducing the phosphorus concentration. **RESTORATION METHODOLOGY**: A “Limno” hypolimnetic aerator was installed in 1971. During 1971-72 the apparatus was used for oxygenation, distribution of slurried alum for phosphorus sorption in the hypolimnion, and addition of bentonite for sediment treatment. Water was also discharged from the hypolimnion via a special siphon tube (continuing to the present). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment decreased the total phosphorus content of the lake water and phytoplanktonic primary production was reduced. There was an increase in water clarity and hypolimnetic oxygen concentrations. Dissolved organic substances were removed to a significant degree and hydrogen sulfide disappeared completely. Studies are continuing. **REFERENCES**: Atlas Copco AB (pers. comm.), Ohle (pers. comm.), Ohle (1972), Overbeck (pers. comm.).

LAKE NAME: Schleinsee
LOCATION: West Germany
SURFACE AREA: 15 ha
MAXIMUM DEPTH: 11.6 m

PROBLEM: Hypolimnetic oxygen depletion during summer thermal stratification. **RESTORATION OBJECTIVE**: To induce artificial mixing and investigate the effects on lake limnology. **RESTORATION METHODOLOGY**: Lake mixing was achieved by forcing the epilimnetic waters down into the hypolimnion. A submersed propellor driven system was used. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During the mixing, nutrients previously contained in the hypolimnion were made available and stimulated in the development of massive algal blooms. "Ploughing" therefore increased lake fertility. **REFERENCES**: Grim (1952).

LAKE NAME: Schliersee
LOCATION: Bavaria, West Germany
SURFACE AREA: 2.2 km^2
MAXIMUM DEPTH: 40.3 m

PROBLEM: Eutrophication mainly the result of domestic wastewater influx. Massive algal blooms (primarily *Lyngbya limnetica* and *Oscillatoria redecki);* oxygen depletion in the hypolimnion; degradation of the whitefish population; and general threat to recreational value. **RESTORATION OBJECTIVE**: To restore the original mesotrophic status of the lake. To reduce the influx of inorganic nutrients thereby limiting plant growth and improving the oxygen balance in the hypolimnion. **RESTORATION METHODOLOGY**: All sewage (excl. storm waters) was diverted from the lake in 1964. The wastewaters are collected and taken to a mechanical-biological treatment plant. The effluent is discharged into a river below the lake. The total costs were about $5,800,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The mean depth and hydraulic residence time are 24.9 m and 1.9 yrs, respectively. Further water quality degradation was halted but no improvements were discernible within one year. By 1967 oxygen was present to 33 m during the summer (only 8 m in 1964); conditions were, however, still generally unsatisfactory. Through 1972, a slow but steady improvement has continued, including: (1) reduced inorganic nutrient content, (2) increased oxygen levels in the benthal region, (3) decreased production of methane in the sludge deposits, and (4) some significant changes in the phytoplankton. **REFERENCES**: Bucksteeg (pers. comm.), Hamm (1968, 1971), Huber (pers. comm.), Liebmann (1970), Oberste Baubehörde im Bayerischen Staatsministerium des Innern (1971), Wieselberger and Hanisch (1966).

LAKE NAME: Spitzingsee
LOCATION: Bavaria, West Germany
SURFACE AREA: 30 ha
MAXIMUM DEPTH: 17 m

PROBLEM: Massive algal blooms; oxygen depletion in the hypolimnion; and degradation of the fish population. **RESTORATION OBJECTIVE**: To stop further deterioration of the limnological conditions within the lake by wastewater diversion. To reverse the eutrophication process. **RESTORATION METHODOLOGY**: Partial collection and diversion of the wastewaters was completed in 1961. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Eutrophication continued to intensify from 1961 and 1965. During the summer there was: (1) oxygen depletion below 12 m, (2) supersaturation of oxygen in the epilimnion (142% at 2 m), (3) extensive areas of bottom sapropel, and (4) high rotifer populations in the plankton. The partial diversion was insufficient to halt the eutrophication process. **REFERENCES**: Liebmann (1965b).

LAKE: Starnberger See
LOCATION: Bavaria, West Germany
SURFACE AREA: 57.2 km^2
MAXIMUM DEPTH: 123 m

PROBLEM: Eutrophication caused mainly by the influx of domestic wastewaters. Oxygen depletion and nuisance planktonic algal growths. **RESTORATION OBJECTIVE**: To reduce the nutrients influx via diversion. To attain or keep a water quality that permits full recreational usage. **RESTORATION METHODOLOGY**: A special canal is being constructed around the entire lake. The wastes (excl. storm water) will be treated and the effluent released downstream from the lake. Construction of the canal began in 1965 and will be completed in the near future. The sewage treatment plant includes mechanical and two stage biological treatment and began operation in 1972 (325 kg BOD_5/day and 250,000 m^3/day). The total cost will be about $30,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The mean depth is 54 m and the hydraulic residence time, 21 yrs. The diversion is about one-half finished. Further deterioration of water quality seems to have stopped; definite results are not yet available. **REFERENCES**: Bucksteeg (pers. comm.), Hamm (1968), Huber (pers. comm.), Kölbing (pers. comm.), Oberste Baubehörde im Bayerischen Staatsministerium des Innern (1971), Wieselberger and Haendel (1971), Wieselberger and Hanisch (1969).

LAKE NAME: Tegeler See
LOCATION: Berlin, West Germany
SURFACE AREA: 4 km^2
MAXIMUM DEPTH: 14 m

PROBLEM: Polluted for the last 90 yrs; main recreation area for the people in northern Berlin. The lake is subject to multiple use and conservation and regeneration of the reed beds has been difficult. **RESTORATION OBJECTIVE**: To limit further nutrient inputs; to remove sediments from the lake; and to restore and manage the more important areas. **RESTORATION METHODOLOGY**: Restoration measures will include elimination of phosphate from the inflow and removal of the upper layer of sediments in the lake. A pilot treatment plant (2 m^3/sec) was constructed for phosphorus precipitation, sorption, and settling. Regulations were enacted to protect the reed stands and in some cases, the areas were enclosed within fences. The muskrat and mute swan *(Cygnus olor)* populations are also controlled to prevent overabundance. Reeds have been replanted in certain locales. The total costs for 1972-86 are estimated at about $1,700,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available; a limnological response to the restoration measures is not expected before 1980-81. **REFERENCES**: Bezirksamt Reinickendorf von Berlin (1971), Hässelbarth (pers. comm.), Senat von Berlin (1971), Sukopp (pers. comm.), Sukopp (1971, 1973), Sukopp and Kunick (1969).

LAKE NAME: Tegernsee
LOCATION: Bavaria, West Germany
SURFACE AREA: 8.9 km^2
MAXIMUM DEPTH: 72.2 m

PROBLEM: Influx of domestic wastewaters; P loading of about 2.1 $g/m^2/yr$ from this source. Excessive growths of *Oscillatoria rubescens;* oxygen depletion in the hypolimnion; and decreased recreational value. **RESTORATION OBJEC-**

TIVE: To stop the continued degradation of the lake and to restore its original water quality. **RESTORATION METHODOLOGY**: Diversion of raw sewage (excluding storm water) from the lake was completed in 1963. A ring canal conducts the sewage from all of the surrounding towns to a mechanical and biological treatment plant. The effluent is discharged into the lake outflow. The total cost was about $16,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The mean depth and hydraulic residence time are 36.3 m and 1.25 yrs, respectively. In 1964 there was no oxygen below 67 m during late summer; by 1967 the concentrations were higher at all depths and anaerobic conditions did not develop. The density of *O. rubescens* also decreased during this period. However, there was little change in other parameters. During the last three years there has been pronounced improvement in water quality: (1) reduction of nutrient levels, (2) increased concentrations of hypolimnetic oxygen during the summer, and (3) desirable changes in fish population characteristics. **REFERENCES**: Bucksteeg (pers. comm.), Hamm (1968, 1971), Huber (pers. comm.), Liebmann (1970), Oberste Baubehörde im Bayerischen Staatsministerium des Innern (1971), Wieselberger and Hanisch (1968).

LAKE NAME: Wahnbachtalsperre
LOCATION: near Bonn, West Germany
SURFACE AREA: 2.2 km^2
MAXIMUM DEPTH: 45 m

PROBLEM: Accelerated eutrophication due to domestic sewage and agricultural runoff. Nuisance plankton blooms. Hypolimnetic oxygen depletions create water quality control problems; the reservoir is used for drinking and industrial water supply. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen levels in the bottom waters in order to provide a dependable high quality water supply. **RESTORATION METHODOLOGY**: An aeration/destratification system was installed in 1961. During the summers of 1961 and 1962, air was supplied at a rate of 2 m^3/min. In 1964, an additional 6 m^3/min of air was delivered to the aerator. In 1966, a hypolimnetic system was substituted (2 m diam, 42 m long tube suspended vertically at 40 m). Air was supplied at 4 m^3/min. The total cost including operation of the 1964 system was $6,250 USA whereas the capital cost of the 1966 system was about $18,000. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In 1961 and 1962, the reservoir was only partially destratified, and anaerobic conditions developed in the hypolimnion by the end of August. In 1964, the reservoir was maintained in a destratified state in the vicinity of the dam for most of the summer, and dissolved oxygen concentrations remained greater than 30% saturation. *Oscillatoria* was distributed throughout the water column, producing a quick die-off. However, destratification increased the temperature of the reservoir to unsatisfactory levels for water supplies. With hypolimnetic aeration, the thermocline remained intact throughout the summer, although it sank to greater depths than usual. The temperature of the hypolimnion also increased from 6° to 10° during the aeration period. Dissolved oxygen remained at more than 30% saturation. Manganese and phosphorus concentrations declined very rapidly after aeration began. Nevertheless, operation of the hypolimnetic aerator did not totally eliminate the water quality problems. **REFERENCES**: Bernhardt (pers. comm.), Bernhardt (1963, 1967, 1968), Bernhardt and Hotter (1967).

LAKE NAME: Wahnbachtalsperre
LOCATION: near Bonn, West Germany
SURFACE AREA: 2.2 km^2
MAXIMUM DEPTH: 45 m

PROBLEM: Accelerated eutrophication due to domestic sewage and agricultural runoff. The reservoir is used for drinking and industrial water supply; water quality problems exist despite operation of a hypolimnetic aeration system. **RESTORATION OBJECTIVE**: To reduce the total phosphorus concentration in the inflow to 10 mg/l thereby decreasing the P loading from 1–2.5 g/m^2/yr. To limit the planktonic algal blooms. **RESTORATION METHODOLOGY**: The major inflow will be treated using iron (III), pH control, and filtration. The treatment plant will have a capacity of about 3.5 x 10^5 m^3/day and will cost $2,500,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Construction had not begun as of 2 June, 1973 but is imminent. Design criteria were developed in a pilot plant. The treated water contained 10 μg P/l or less and bioassays indicate that productivity will be reduced significantly. **REFERENCES**: Bernhardt (pers. comm.), Bernhardt et al. (1971).

LAKE NAME: Haleji Lake
LOCATION: West Pakistan
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundant macrophytes, primarily *Hydrilla*, *Potamogeton*, and *Vallisneria*. **RESTORATION OBJECTIVE**: To control the macrophytes. **RESTORATION METHODOLOGY**: Grass carp *(Ctenopharyngodon idella)* were stocked as a potential biological control agent. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The carp effectively reduced the macrophytes by ingestion. **REFERENCES**: Ahmad (1968).

LAKE NAME: Lake Bled
LOCATION: Groenjska Valley, Bled district, Yugoslavia
SURFACE AREA: 1.4 km^2
MAXIMUM DEPTH: 30.2 m

PROBLEM: Advancing eutrophy; the largest inflow is polluted. **RESTORATION OBJECTIVE**: To guard the lake against further eutrophication; to record the lake phenomena before and after initiation of the restoration measures. **RESTORATION METHODOLOGY**: The nearby River Radovna contains cold, well-oxygenated, good quality water. Water is diverted from the river into the lake in spring and in autumn. This will reduce the hydraulic residence time from about 2.5 to 0.5–1.0 years. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The introduction of river water began May, 1964. Studies were underway, but the effects of the experiment were not presented in the report. Various physico-chemical and biological parameters were under investigation. **REFERENCES**: Sketelj and Rejic (1966).

LAKE NAME: Lake Palic
LOCATION: near Subotica, Yugoslavia
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Influx of municipal wastewaters. Hydrogen sulfide production. Extensive fishkills. Inhospitable conditions for most forms of aquatic life. **RESTORATION OBJECTIVE**: To restore the recreational value of the lake. **RESTORATION METHODOLOGY**: The lake was drained and the bottom sludge is now being removed by dry land excavation techniques. A diversion channel is also being formed to transport the municipal wastes away from the lake. Wastewater treatment facilities will be constructed at an estimated cost of

$4,500,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The lake will be refilled in 1974. Results are, therefore, not yet available. **REFERENCES**: Anderson (1973).

LAKE NAME: Fish ponds
LOCATION: central Arkansas, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of vegetation. **RESTORATION OBJECTIVE**: To determine the effectiveness of diuron for vegetation control. **RESTORATION METHODOLOGY**: Diuron was applied in powder and spray form at rates of 0.56 to 1.1 kg/ha (one application of 0.03 kg/ha for 15 ha). The costs were $7.40 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results were best during May-July; diuron remained toxic for about three weeks after application. Good control was noted for bladderwort *(Utricularia)*, naiad *(Najas)*, pondweed *(Potamogeton)*, watershield *(Brasenia)*, waterlily *(Nymphaea)*, parrotfeather *(Myriophyllum)*, spikerush *(Eleocharis)*, and pickerelweed *(Pontederia)*. Results for cattail *(Typha)* were varied, and it was not effective against muskgrass *(Chara)*, duckweed *(Lemna)*, lizardtail *(Saururus)*, and ducksmeat *(Spriodela)*. Phytoplankton blooms were also reduced; no fishkills occurred but oxygen depletion was prevented by treating only a part of the heavily infested (vegetation) ponds. The diuron treated water could not be used for irrigation during the season of application. **REFERENCES**: Grizzell, Jr. (1966).

LAKE NAME: Irrigation ditches
LOCATION: Florida, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of water lettuce *(Pistia stratiotes)*. **RESTORATION OBJECTIVE**: To determine the most effective herbicide. **RESTORATION METHODOLOGY**: Herbicides were applied to 1.8 ha plots in 1961 at 0.56, 1.12, and 1.68 kg/ha for diquat; 1.12 kg/ha for amitrole-T; and 2.24 and 4.5 kg/ha for 2,4-D. Additional testing was done during 1960-62 on 23.2 m^2 plots and with diquat in 1961 and 1962. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In small plot testing diquat, at rates exceeding 0.56 kg/ha, was the most effective herbicide. Large-scale testing with diquat in 1961 yielded 50, 75, and 85% control of water lettuce after two months at rates of 0.56, 1.12, and 1.68 kg/ha, respectively. The use of a wetting agent increased the effectiveness slightly. Aerial applications and spraying by boat produced similar effects. **REFERENCES**: Weldon and Blackburn (1967).

LAKE NAME: Small ponds
LOCATION: Georgia, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundant macrophytes and algae. **RESTORATION OBJECTIVE**: To test the effectiveness of various toxicants for vegetation control. **RESTORATION METHODOLOGY**: Fenec, simazine, atrazine, prometryne, diquat, and paraquat were used at a wide range of application rates. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Fenec was an effective macrophyte control agent except for the lily family, *Nymphaeaceae*, when applied to exposed areas during winter drawdowns at rates of 11.2 and 22.4 kg active ingredient/ha. It also controlled emerged *Potamogeton natans* at 1 mg/l. Filamentous algae were effectively controlled with simazine, atrazine, and prometryne at application rates of 0.5 to 1 mg/l. Algal growth was inhibited or eliminated for six weeks. Diquat and paraquat were effective non-selective herbicides at concentrations of 0.25 mg cation/l and higher. Duckweed *(Lemna)* was also highly susceptible. The lily family was the most tolerant. No adverse effects on fish, invertebrates, or plankton were noted. **REFERENCES**: Pierce et al. (1964).

LAKE NAME: Farm ponds
LOCATION: Iowa, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundant vegetation in small agricultural and recreational ponds. **RESTORATION OBJECTIVE**: To reduce the vegetation in order to enhance various uses of the ponds. **RESTORATION METHODOLOGY**: Black plastic sheeting was floated on the surface of the water. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The degree of success varied with the plant species; however, most of the plants were controlled in 3-4 weeks. *Chara vulgaris* and *Sagittaria latifolia* were, in particular, resistant to this method of control. **REFERENCES**: Mayhew and Runkel (1962).

LAKE NAME: Commercial waterways
LOCATION: Louisiana and other Gulf Coast states, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Excessive growth of water hyacinth *(Eichornia crassipes)* and alligaterweed *(Alternanthera philoxeroides)*. Interference with navigation. **RESTORATION OBJECTIVE**: To maintain the waterways in a navigable condition. **RESTORATION METHODOLOGY**: The macrophytes were eliminated mechanically by crushing and chopping at a cost of approximately $80,000 USA/yr (1938). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were very effectively killed by the equipment but high reproductive rates necessitated a continual effort. **REFERENCES**: Wunderlich (1938, 1966).

LAKE NAME: Farm ponds
LOCATION: Missouri, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of macrophytes. Interference with commercial and recreational fish production. **RESTORATION OBJECTIVE**: To eliminate the macrophytes. **RESTORATION METHODOLOGY**: Black polyethylene sheets were floated on the surface of the pond. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Most of the macrophytes were controlled within 2-3 weeks. **REFERENCES**: Whitley (1964).

LAKE NAME: Farm ponds
LOCATION: Missouri, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of vegetation. **RESTORATION OBJECTIVE:** To evaluate the vegetation control effectiveness of five different chemicals. **RESTORATION METHODOLOGY:** Casaron, diquat, paraquat, fenac, and ammonia were applied at various concentrations. Treatments involved entire ponds and open plots. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Granular casaron applied before emergence at 11.2-22.4 kg/ha gave 100% control of *Chara.* Casaron showed no acute toxic effects on the plankton. Whole pond treatments with diquat and paraquat at concentrations of 0.13 to 0.50 mg/l gave good control of the filamentous algae. Paraquat at 0.25 mg/l eliminated the blue-green algae, *Anabaena* and *Anacystis,* while the green algae, *Staurastium* and *Cosmarium,* increased. After treatment with diquat at 0.50 mg/l one species of blue-green algae, *Aphanizomenon,* disappeared while another, *Anabaena,* increased. Fenac gave 100% control of nine species of macrophytes at 0.50 to 3.0 mg/l. *Chara* and filamentous algae were unaffected. Partial treatments in open plots were ineffective. Ammonia concentrations of 20 mg/l in whole pond treatments eliminated most of the plankton and benthos; however, a few organisms were only reduced and 2 organisms increased following treatment. *Chara* was killed at that concentration. **REFERENCES:** Whitley (1965).

LAKE NAME: Farm ponds
LOCATION: Missouri, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of vegetation. **RESTORATION OBJECTIVE:** To study the effectiveness of dichlobenil for vegetation control and to determine the ecological consequences of treatment. **RESTORATION METHODOLOGY:** Applications were made to open plots and plastic enclosures within selected ponds, 74 tests in all. Granular and wettable powder formulations were used in field experimentation. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Dichlobenil gave seasonal control of pondweeds *(Potamogeton)* when applied at 22.4 kg/ha. The success rate was about 85% for soil treatments before reflooding, 25% for pre-emergence treatments, and 5% for post-emergence treatments. The compound was also very effective in controlling *Najas.* Results were improved at higher application rates; 44.9 kg/ha produced a 90% success rate for pre-emergence treatments. Some control of *Chara* and other filamentous algae was also achieved. Concentrations up to 7 mg/l (44.9 kg/ha) were not toxic to fish. Nutrients were released by the decomposing vegetation; after treatment there was a 70% and 100% increase in total nitrogen and total phosphorus concentration, respectively. Subsequent algal blooms were common. **REFERENCES:** Walker (1964b).

LAKE NAME: Farm ponds
LOCATION: Missouri, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of vegetation. **RESTORATION OBJECTIVE:** To study the effectiveness of diuron, fenuron, monuron, neburon, and TCA mixtures for vegetation control and to determine the ecological consequences of treatment. **RESTORATION METHODOLOGY:** Applications were made to entire ponds, open plots, and plastic enclosures. Effectiveness was judged on the basis of the degree of control observed over at least a three month period. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Monuron, fenuron, and their respective TCA mixtures were effective herbicides and were not seriously adverse to fish and invertebrate populations at concentrations up to 10, 7, and 4 mg/l, respectively. Diuron and phenylurea (TCA mixtures) were also effective herbicides but were toxic to fish. Neburon was not an effective herbicide. Post-emergence treatments were least effective. Pre-emergence treatments controlled the vegetation for 2-6 months, and soil applications of 22.4-44.9 kg/ha prior to reflooding often achieved complete control and soil sterilization for up to 2-3 years. Each formulation–wettable powder, liquid concentrate, and granular–was most effective for specific situations. **REFERENCES:** Walker (1965).

LAKE NAME: Farm ponds
LOCATION: Ashland Wildlife Area, Boone Co., Missouri, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of macrophytes, especially submergents. **RESTORATION OBJECTIVE:** To determine the effectiveness of endothall for the control of vegetation and to study the ecological consequences of treatment. **RESTORATION METHODOLOGY:** Applications were made to whole ponds, open plots, and plastic enclosures. On the plots, 270 tests were made on 19 submerged species with disodium endothall and 94 tests on 11 species with the di-N, N-dimethylococoamine salt of endothall (coded as TD-47). **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Applications of 1-3 mg/l made to whole ponds or plastic enclosures were effective on most submerged species. Young growth was much easier to control than dense older growth. Marginal or partial treatments required higher rates. Rapid dispersion reduced the effectiveness of open plot treatments. *Chara* and other filamentous algae were common among the regrowth following macrophyte eradication. TD-47 was more effective than disodium endothall. Macrophyte control for more than one month was achieved in 72 of the 94 tests. TD-47 was at least 10 times more active as a herbicide and about 100 times more toxic to fish, precluding application to whole ponds or lakes at rates exceeding 5 mg/l. Neither of the formulations affected fish food organisms directly; however, macrophyte decomposition resulted in greatly increased nutrient concentrations and BOD. These changes produced modifications in the faunal community. **REFERENCES:** Walker (1963).

LAKE NAME: Farm ponds
LOCATION: Busch Memorial Wildlife Area, St. Charles Co., Missouri, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of macrophytes, especially submergents. **RESTORATION OBJECTIVE:** To study the effectiveness of simazine and other s-triazines, especially atrazine, for vegetation control and to determine the ecological consequences of treatment. **RESTORATION METHODOLOGY:** Applications were made to whole ponds, open plots, and plastic enclosures. Simazine was applied at rates of 0.5 to 10 mg/l in 414 tests of 21 species of submergents and atrazine, at rates of 0.2 to 6 mg/l to 11 species of submergents. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Simazine was effective in 215 of the 414 tests; the granular formulation was most successful against submergents while the wettable powder was a good algal inhibitor. Emergent species were best controlled by application of 11.2-22.4 kg or more/ha before emergence. Partial to temporary control only was possible for American lotus *(Nelumbo lutea)*, cattails *(Typha latifolia)*, sweetflag *(Acorus calamus)*, and duckweed *(Lemna minor)*, at rates of about 45 to 135 kg/ha. Atrazine concentrations of 0.5 to 1 mg/l effectively controlled most filamentous algae and pondweeds. Spraying the wettable powder was the most successful application technique. The duration of phytotoxicity varied from seasonal at 0.5 mg/l to over a year at 1 mg/l (algae were rarely inhibited for more than one season). Macrophyte elimination often resulted in the occurrence of phytoplankton blooms and increased zooplankton abundance. Both simazine and atrazine required 2-6 weeks before phytotoxicity symptoms were noted. Fish toxicity was not observed and the dissolved oxygen content was not depleted following treatment. Atrazine was somewhat toxic to the bottom fauna; however, the faunal community was, in general, affected only indirectly through reduction of the macrophytes. **REFERENCES**: Walker (1964a).

LAKE NAME: Several lakes
LOCATION: New Hampshire, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Nuisance algal blooms. Poor water quality. Used for water supply. **RESTORATION OBJECTIVE**: To reduce the algal blooms thereby correcting some of the related taste and odor problems. **RESTORATION METHODOLOGY**: Copper sulfate was applied by "bag dragging" in order to achieve an even distribution of the algicide to the 3.1 m depth. The average concentration was 0.18 mg/l and the cost was approximately $0.44 USA/kg. Treatment of one 137 ha lake cost $340. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The taste and odor problems, caused primarily by *Dinobryon*, were alleviated by treatment with copper sulfate. Successful results were attained when the algicide was used either as a preventive or as a curative. **REFERENCES**: Frost (1960).

LAKE NAME: Several lakes
LOCATION: New Hampshire, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Influx of nutrients via municipal and industrial wastewater treatment plant effluents. Nuisance algal blooms. **RESTORATION OBJECTIVE**: To reduce the algal blooms. **RESTORATION METHODOLOGY**: Copper sulfate was applied to control the algae. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Copper sulfate concentrations effective against algae were not lethal to smelt *(Osmerus mordax)* adults or eggs. One fishkill occurred but was due to the usage of unnecessarily high concentrations of copper sulfate; later applications using lower dosages controlled the algae without harm to the fish. Analyses of the bottom muds from one lake after three years of treatment (28,600 kg of copper sulfate) showed copper concentrations equal to or below those in samples from two untreated upstream lakes. **REFERENCES**: Frost (1963).

LAKE NAME: Farm ponds
LOCATION: central New York, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of macrophytes and algae. **RESTORATION OBJECTIVE**: To determine the effects of silvex treatment upon the macrophytes and plankton of small, shallow ponds. **RESTORATION METHODOLOGY**: Silvex was applied in August, 1961 and 1962. The chemical was sprayed on the surface in sufficient quantities to yield a concentration of 2 mg acid equivalent/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment resulted in excellent control of pondweeds *(Potamogeton)* and duckweed *(Lemna)*; however, filamentous algae, *Chara*, and certain emergent species were not controlled adequately. Pre- and post-treatment sampling revealed no effect on phytoplankton, zooplankton, and fish. Whenever large amounts of vegetation were killed, alkalinity increased and the oxygen levels decreased (about 2-4 mg/l). **REFERENCES**: Cowell (1967).

LAKE NAME: Hatchery ponds
LOCATION: U.S. Fish & Wildlife Service, Leetown, West Virginia, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Excessive growth of macrophytes and algae. **RESTORATION OBJECTIVE**: To control the vegetation under hard water conditions (up to 260 mg/l methyl orange alkalinity). **RESTORATION METHODOLOGY**: Sodium arsenite and copper sulfate were applied at concentrations of up to 5 and 2 mg/l, respectively. The chemicals were added to the ponds by spraying on the surface. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Sodium arsenite was more effective than copper sulfate for the control of *Hydrodictyon, Oedogonium, Cladophora,* and *Zygnema;* but was ineffective for *Spirogyra, Oscillatoria,* and *Chara.* Copper sulfate treatment at 2 mg/l was adequate for all purposes. Neither toxicant was useful for limiting the growth of hard-stemmed emergents (e.g., *Nymphaea, Typha, Scirpus).* No toxic effects were noted for the fish population; however, mortalities occurred in several ponds due to decreased oxygen levels. During the summer, the decomposing vegetation caused high BOD's for about two days. **REFERENCES**: Surber (1943).

LAKE NAME: One (1) pond
LOCATION: Alabama, USA
SURFACE AREA: 9 ha
MAXIMUM DEPTH: --

PROBLEM: Unbalanced fish population; overabundant, small bluegills *(Lepomis macrochirus).* **RESTORATION OBJECTIVE**: To improve the fish population dynamics by reducing the number of small bluegills. **RESTORATION METHODOLOGY**: Rotenone was applied around the shoreline on 1 June, 1949 to yield a concentration of 1 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 117 kg of fish/ha were eliminated, including 93 kg/ha of small and intermediate-sized bluegills. Fish population balance did not result from treatment and bluegill growth did not improve significantly. **REFERENCES**: Swingle et al. (1953).

LAKE NAME: One (1) lake
LOCATION: Alabama, USA
SURFACE AREA: 24 ha
MAXIMUM DEPTH: --

PROBLEM: Overabundant, small bluegills *(Lepomis macro-*

chirus). **RESTORATION OBJECTIVE**: To restore fish population balance by reducing the number of small bluegills. **RESTORATION METHODOLOGY**: One-third of the lake was treated with rotenone to give a concentration of 1 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Large numbers of small and intermediate-sized bluegills were killed. Approximately 450 kg of largemouth bass *(Micropterus salmoides)* also died, apparently because they happened to be feeding in the area at the time of poisoning. **REFERENCES**: Swingle et al. (1953).

LAKE NAME: One (1) pond
LOCATION: Alabama, USA
SURFACE AREA: 11 ha
MAXIMUM DEPTH: ---

PROBLEM: Poor sport fishery; overabundant, small bluegills *(Lepomis macrochirus)*. **RESTORATION OBJECTIVE**: To restore the population balance by reducing the number of small bluegills. **RESTORATION METHODOLOGY**: The pond was treated with rotenone on 17 and 24 June, 1949. Only the shoreline area was treated. Largemouth bass *(Micropterus salmoides)* fingerlings were restocked at the rate of 370/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The two poisonings eliminated about 92 kg of fish/ha, including 90 kg/ha of small and intermediate-sized bluegills. Subsequently, the fish population came into balance, the bluegills reproduced successfully, and there was an improvement in fishing. **REFERENCES**: Swingle et al. (1953).

LAKE NAME: One (1) pond
LOCATION: Alabama, USA
SURFACE AREA: 24 ha
MAXIMUM DEPTH: ---

PROBLEM: Unbalanced fish population. Poor sport fishery. **RESTORATION OBJECTIVE**: To eliminate a significant portion of the population of small bluegills *(Lepomis macrochirus)*. **RESTORATION METHODOLOGY**: Rotenone was used once in 1949 and twice in 1950. An entire section of the pond was treated in 1949; only the shoreline was treated in 1950. After the 1950 treatments, approximately 250 largemouth bass *(Micropterus salmoides)* fingerlings/ha were stocked. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The fish population characteristics were not improved as a result of the first treatment. After the treatments in 1950 the population came into balance and there was an improvement in fishing. **REFERENCES**: Swingle et al. (1953).

LAKE NAME: One (I) pond
LOCATION: Arizona, USA
SURFACE AREA: 8l ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundant macrophytes. **RESTORATION OBJECTIVE**: To control the macrophytes chemically without using copper sulfate or sodium arsenite. **RESTORATION METHODOLOGY**: Ortho-dichlorobenzene was applied at high pressure through a manifold of nozzles under the surface of the water. Trichlorobenzene and carbon disulfide were also used. The chemical costs in 1949 ranged from $62 to $124 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Ortho-dichlorobenzene was the most useful toxicant. *Myriophyllum* was eliminated by a concentration of 187 l/ha and *Potamogeton pectinatus*, by 750 l/ha. The fish trapped in the treated area were killed; 40% of the pond could be treated without imparting an undesirable flavor to the water. Trichlorobenzene was an effective macrophyte control agent but the water and fish flesh had a disagreeable taste after treatment. Carbon disulfide was about 25% less effective than either of the other two herbicides. **REFERENCES**: Eicher (1949).

LAKE NAME: One (I) pond
LOCATION: near Morrison, Colorado, USA
SURFACE AREA: 1780 m^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundant vegetation. **RESTORATION OBJECTIVE**: To determine the effectiveness of paraquat for vegetation control and to study its effect on the fish population. **RESTORATION METHODOLOGY**: Sufficient paraquat was applied to yield a concentration of 1.14 mg/l. Residue analyses were performed periodically on the algae, water, sediments, and fish. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: *Chara* was almost completely eliminated within 16 days; *Spirogyra* was controlled initially but again became plentiful after three months. Over 3 mg/l paraquat was still present in the sediments after 99 days. Fish toxicity was highest 1-2 days after treatment, with bluegills *(Lepomis macrochirus)* the most susceptible species and catfish *(Ictalurus punctatus)* the most tolerant. **REFERENCES**: Earnest (1971).

LAKE NAME: One (I) pond
LOCATION: near Pensacola, Florida, USA
SURFACE AREA: 1500 m^2
MAXIMUM DEPTH: 0.4 m

PROBLEM: Overabundant vegetation. **RESTORATION OBJECTIVE**: To determine the vegetation control effectiveness of dichlobenil and to study its effect on oxygen production, plankton dynamics, and water chemistry. **RESTORATION METHODOLOGY**: Dichlobenil was applied as a wettable powder at a concentration of 1 mg/l. The chemical was injected beneath the surface using a sprayer on 3 April, 1968. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: All of the *Potamogeton pectinatus* and about 80% of the *Chara* were eliminated from the pond. As the vegetation died, blooms of phytoplankton and zooplankton occurred, but no changes were observed in the water chemistry at any time during the period of herbicidal effects. Pre-treatment conditions returned after approximately three months. **REFERENCES**: Walsh et al. (1971).

LAKE NAME: One (I) farm pond
LOCATION: Boone Co., Missouri, USA
SURFACE AREA: 1050 m^2
MAXIMUM DEPTH. 2.1 m

PROBLEM: Overabundant macrophytes. **RESTORATION OBJECTIVE**: To determine the effectiveness of silvex as a macrophyte control agent. **RESTORATION METHODOLOGY**: Seven plastic enclosures, each 20 m^2 with a maximum depth of 1.2 m, were treated on 21 July, 1961 with potassium salt silvex, 2-(2,4,5-trichlorophenoxy) propionic acid, in granular form with 20% active ingredient. The dosages were 4.6 and 2.8 mg/l active ingredient in three each of the enclosures. One of the enclosures was not treated and served as a control. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: *Sagittaria* and *Potamogeton* disappeared by 18 August and 29 September, respectively. By 22 November *Jussiaea* was also eliminated and *Typha* and *Juncus* were reduced by 90%. The following summer some scattered *Potamogeton* and *Jussiaea* reappeared belatedly but *Sagittaria* was still absent.

Throughout the second summer, *Typha* and *Juncus* occupied only 10% of the area in which they were found prior to treatment. *Cabomba, Pithophora* and *Spirogyra* appeared to be unaffected by silvex. Treatment with 2.8 mg/l silvex produced good control of the macrophytes; concentrated treatment at 4.6 mg/l was not visibly more effective. **REFERENCES**: Harp and Campbell (1964).

LAKE NAME: One (I) pond
LOCATION: Milwaukee Co., Wisconsin, USA
SURFACE AREA: 2 ha
MAXIMUM DEPTH: 3.1 m

PROBLEM: Intense growth of macrophytes *(Myriophyllum sp).* Restricted recreational use. Winterkills. **RESTORATION OBJECTIVE**: To control the macrophytes without altering the water quality. **RESTORATION METHODOLOGY**: Confined areas were treated with two herbicides, diquat and endothall, at concentrations of 3 mg/l in August, 1970. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were completely controlled within 14 days and the surface was macrophyte free within 21 days. Nitrogen and phosphorus concentrations increased while the oxygen levels decreased in the surface waters. Nuisance algal blooms occurred as a result of the increased availability of nutrients. The pond was invaded by pondweed *(Potamogeton foliosus)* the following growing season. **REFERENCES**: Daniel (pers. comm., 1971).

LAKE NAME: Two (2) ponds
LOCATION: Arizona, USA
SURFACE AREA: 2020 m^2 and 1.2 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of vegetation. **RESTORATION OBJECTIVE**: To reduce the light penetration by dye introduction. **RESTORATION METHODOLOGY**: Nigrosine dye was applied at rates of approximately 1.1 and 2.2 kg/ha. Additional dye was added whenever necessary to maintain the original concentrations for a three month period. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The water clarity decreased from about 4.1 m to 1.5 m after the treatments. The water temperature near the bottom dropped and there was a temporary increase in the plankton. **REFERENCES**: Eicher (1947).

LAKE NAME: Two (2) ponds
ABAC Pond
J. E. Taylor Pond
LOCATION: Georgia, USA
SURFACE AREA: 8000 m^2 each
MAXIMUM DEPTH: ---

PROBLEM: Overabundant population of small bluegills *(Lepomis macrochirus).* Poor sport fishery. **RESTORATION OBJECTIVE**: To evaluate the effect of overwinter drawdown and predator stocking (largemouth bass, *Micropterus salmoides)* upon the bluegill population. **RESTORATION METHODOLOGY**: During October-January, 1962 the ponds were lowered to 0.2 and 0.3 ha for 80 and 45 days, respectively. In one pond (lowered to 0.2 ha) 86 bass, 7.6-10.2 cm in length, were stocked per hectare during the drawdown. In the other pond, 185 bass (15.2-30.5 cm in length) were stocked per hectare. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In both ponds the population of small bluegills was greatly reduced and subsequently the bass and bluegills reproduced successfully. Bluegill growth increased slightly by fall, 1963, but fishing success did not improve significantly. **REFERENCES**: Pierce et al. (1963).

LAKE NAME: Two (2) lakes
Elk Creek Lake
Springs Valley (Tucker) Lake
LOCATION: Orange & Washington Cos., Indiana,USA
SURFACE AREA / MAXIMUM DEPTH:
Elk Creek Lake (19.4 ha) / 6.0 m
Springs Valley Lake (Tucker Lake) (57.1 ha) / 8.5 m

PROBLEM: Overpopulation of slow-growing bluegills *(Lepomis macrochirus).* **RESTORATION OBJECTIVE**: To determine if fishing regulations were significantly affecting largemouth bass *(Micropterus salmoides)* predation on the bluegills. **RESTORATION METHODOLOGY**: A 30.4 cm size limit was applied to the bass fishery in one lake with no size limit in the other. Both lakes were formed in 1962 and opened to fishing in 1965. Evaluations were conducted in 1966. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The average lengths of Age 1 and 2 bluegills were highest in the lake without a size limit, whereas the Age 3 bluegills were larger in the lake with a size limit. Therefore, any increase in the bluegill cropping rate that may have resulted from restrictions on the largemouth bass harvest was insufficient to improve the bluegill growth rate. **REFERENCES**: Beard (1967).

LAKE NAME: Two (2) ponds
Howard Roberts Pond
Ray Jansen Pond
LOCATION: eastern Nebraska, USA
SURFACE AREA: 4050 m^2 each
MAXIMUM DEPTH: ---

PROBLEM: Excessive turbidity. Reduced light penetration and restricted biological productivity. **RESTORATION OBJECTIVE**: To increase the water clarity. **RESTORATION METHODOLOGY**: The Howard Roberts Pond was treated with 6 mg/l of Purifloc C-31 on 26 August, 1968 and 18 August, 1969. Purifloc C-31 was also applied to the Ray Jansen Pond at 22 mg/l on 26-27 September, 1969. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The turbidity was reduced from 550 to 30 JTU within six days after the first treatment in the Howard Roberts Pond. It remained at 20-30 JTU until high runoff the next spring. The second treatment lowered the turbidity from 178 to 8 JTU within four days. Readings of 1.2–8.5 JTU were recorded through March, 1970. Water clarity increased from 9 cm before the first treatment to 94 cm in September, 1969; this was later reduced to 58 cm due to an increase in the nannoplankton. Before treatment of the Ray Jansen Pond, the turbidity was 700–1260 JTU; after treatment there was a gradual decrease to 90 JTU within six days. The water clarity increased from 2–6 cm to 22–24 cm. Turbidity remained low until high runoff the next spring. The applications had little effect on temperature and water chemistry and the response of the zooplankton and benthos communities was minimal if any. When the turbidity decreased there was an increase in fish feeding activity. **REFERENCES**: McDonald (undated).

LAKE NAME: Two (2) ponds
Pond of Safety
Swains Pond

LOCATION: New Hampshire, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Undesirable characteristics of the fish population; overabundant panfish. **RESTORATION OBJECTIVE**: To determine the effectiveness of chlorine as a piscicide. **RESTORATION METHODOLOGY**: About 0.14 kg of calcium hypochlorite (24% free chlorine) was dissolved in 4 l of water and applied directly to the panfish nests or under schools of young panfish in Swains Pond. A total of 295 kg of calcium hypochlorite was applied by hand and by plane to the Pond of Safety. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Fish and eggs were killed by the released chlorine but there were some definite problems apparent with each treatment method. Chlorine dispersed quickly and dilution was rapid in the spot treatment test. In the Pond of Safety few fish were killed and little chlorine was measured in the water after application. Rapid neutralization apparently occurred due to organic matter in the bottom sediments. **REFERENCES**: Jackson (1962).

LAKE NAME: Two (2) lakes
Brush Lake
Long Lake
LOCATION: North Dakota, USA
SURFACE AREA / MAXIMUM DEPTH:
Brush Lake (65 ha) / 7 m
Long Lake (118 ha) / 7 m

PROBLEM: Undesirable characteristics of the fish population; slow-growing panfish. **RESTORATION OBJECTIVE**: To determine the effect of population reduction upon the growth rate of yellow perch *(Perca flavescens)*. **RESTORATION METHODOLOGY**: The lakes were treated in 1959 and 1960 with toxaphene at a concentration of 10 μg/l. **RESULTS(OR STATUS FOR ONGOING PROJECTS)**: All young-of-the-year yellow perch were eliminated from both lakes. Yellow perch (Age 1 and older) density was reduced by 91 and 79% in Brush and Long lakes, respectively. Fathead minnows *(Pimephales promelas)* were stocked after treatment. During the 2 years of study following treatment, the growth rate increased greatly in Brush Lake; in Long Lake the growth rate did not increase until the second growing season. **REFERENCES**: Henegar (1966), Warnick (1966).

LAKE NAME: Two (2) lakes
LOCATION: near Sunnyside and Spokane, Washington, USA
SURFACE AREA: 13 and 43 ha
MAXIMUM DEPTH: 1.5 and 2.3 m

PROBLEM: Infestation with waterlily *(Nymphaea* sp.). **RESTORATION OBJECTIVE**: To determine the susceptibility of two species of waterlily to dichlobenil (alone or in combination with 2,4-D) and to evaluate some of the side effects of treatment. **RESTORATION METHODOLOGY**: Dichlobenil granules were applied to open water plots, about 233 m^2 in size, at rates of 8.4 and 16.8 kg/ha on 10 April, 1967, after waterlily emergence. One-half of each plot treated at 8.4 kg/ha was retreated at the same rate on 11 July, 1968. On 3 April and 31 March, 1968, several open water plots, about 58 m^2 in size, were also treated with 4.5, 9, and 13.5 kg/ha of dichlobenil–either alone or in combination with 4.5, 9, and 13.5 kg/ha of 2,4-D, respectively. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Waterlilies were controlled initially but rapid regrowth occurred in the smaller plots due to encroachment from the border areas. Combinations of dichlobenil and 2,4-D were less effective than dichlobenil alone at each of the dosages. Pondweed *(Potamogeton* spp.) did not invade the treated areas. Herbicide residues were found in sediment samples taken outside of the treated areas. **REFERENCES**: Comes and Morrow (1971).

LAKE NAME: Two (2) lakes
Corrine
George
LOCATION: Vilas Co., Wisconsin, USA
SURFACE AREA:
Corrine (14.6 ha)
George (17.3 ha)
MAXIMUM DEPTH: --

PROBLEM: Overabundant population of slow-growing yellow perch *(Perca flavescens)*. **RESTORATION OBJECTIVE**: To reduce the population of yellow perch by stocking predator species, thereby stimulating the growth rate. **RESTORATION METHODOLOGY**: In May, 1956, 400 yearling muskellunge *(Esox masquinongy)* were stocked in George Lake and in October, 1956, 395 young-of-the-year muskellunge were placed in Corrine Lake. The fish population was subsequently studied for nine years. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Within one to three years, the yellow perch population decreased from over 10,000 and 30,000 individuals for George and Corrine lakes, respectively, to a density too low to estimate. There was, however, a numerical recovery by the end of the study. Population levels of largemouth bass *(Micropterus salmoides)* also decreased, although strong year-classes were produced; the opposite was true for smallmouth bass *(Micropterus dolomieui)*. The growth rate of yellow perch (ages 1 and 2) were significantly increased after predator stocking; but the length-weight relationship was unchanged. The annual survival rate for the muskellunge was 0.8. REFERENCES: Gammon and Hasler (1965), Schmitz and Hetfeld (1965).

LAKE NAME: Three (3) ponds
LOCATION: Alabama, USA
SURFACE AREA: 4.4 to 8.9 ha
MAXIMUM DEPTH: 2.7 to 3.7 m

PROBLEM: Low dissolved oxygen levels; fishkills. Surface agitators failed to maintain oxygen concentrations above 1 mg/l in these catfish *(Ictalurus punctatus)* ponds. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen conditions during the summer in order to prevent fishkills. **RESTORATION METHODOLOGY**: An air blower rated at 18 l/sec was installed at each pond; air was introduced at the bottom through the end of a 3.2 cm diameter pipe. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The aerators maintained dissolved oxygen levels of 1 mg/l or higher in the deepest waters except during brief periods following plankton die-offs. Dissolved oxygen levels in the surface waters remained satisfactory at all times following installation of the aerators. **REFERENCES**: Smitherman (undated).

LAKE NAME: Three (3) ponds
LOCATION: Alabama, USA
SURFACE AREA: 4,050 m^2 each
MAXIMUM DEPTH: --

PROBLEM: Overabundant small bluegills *(Lepomis macrochirus)*; unbalanced fish population. **RESTORATION OBJECTIVE**: To restore population balance by eliminating a significant percentage of the small bluegills. **RESTORATION METHODOLOGY**: Rotenone was applied around the shoreline of each pond to yield a concentration of 1 mg/l. Pond 1 was treated on 21 June, 1948; Pond 2, on 21 and 23 June; and Pond 3, on 19 July. Each pond was drained on 26 October in order to determine the effectiveness of treatment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In Pond 1 about one-third of the large bass *(Micropterus salmoides)*, one-half of the white crappie *(Pomoxis annularis)*, and 85 to 90% of the small and intermediate-sized bluegills were killed. None of the large bluegills were affected. In Pond 2 approximately 20 to 25% of the large bass were killed but none of the large bluegills. About 40,000 small and intermediate-sized bluegills were eliminated; successful reproduction of bluegills occurred after treatment whereas seining in May and June before treatment had not produced recent progeny of either bluegills or largemouth bass in any of the ponds. In Pond 3 none of the large bass or bluegills were harmed but large numbers of small and intermediate-sized bluegills were killed. Partial treatment brought the fish population into balance only in Pond 2 where two applications were involved. **REFERENCES**: Swingle et al. (1953).

LAKE NAME: Three (3) reservoirs
Alpine
Bon Tempe
Nicasio
LOCATION: Marin Co., California, USA
SURFACE AREA: 52 to 350 ha
MAXIMUM DEPTH: 27 to 40 m

PROBLEM: Nuisance growths of blue-green algae. Poor hypolimnetic water quality due to high iron and manganese concentrations and production of objectionable tastes and odors. All three reservoirs are used for water supply. **RESTORATION OBJECTIVE**: To improve the deep water quality and to reduce the number of copper sulfate treatments required to control the algae. **RESTORATION METHODOLOGY**: Aerators were installed near the bottom of Bon Tempe and Nicasio Reservoirs in 1970 and are operated from about April to October each year. An aerator was also installed in Alpine Reservoir in late 1972. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The aerators maintain destratified conditions and the hypolimnetic water quality has been improved. Algal growth patterns have been successfully altered, enabling a reduction in the copper sulfate treatments. **REFERENCES**: Cuneo (pers. comm.).

LAKE NAME: Three (3) lakes
Lake Granby
Grand Lake
Shadow Mountain Lake
LOCATION: Grand Co., Colorado, USA
SURFACE AREA / MAXIMUM DEPTH:
Lake Granby (20.4 km^2) / 67 m
Grand Lake (2.1 km^2) / 81 m
Shadow Mountain Lake (5.5 km^2) / 11 m

PROBLEM: Nuisance algal blooms in late summer. **RESTORATION OBJECTIVE**: To control the algal blooms and to protect the lakes against any further degradation. **RESTORATION METHODOLOGY**: A regional wastewater collection system and treatment facility is planned at an estimated cost of $4,334,971 USA. The effluent will not enter the lakes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Studies are now underway to quantify the pre-treatment limnological conditions in the lakes. **REFERENCES**: Bowman (pers. comm.), Hinman (1969), Misbach (pers. comm.), Nelson, Haley, Patterson and Quirk, Inc. (to be published), U. S. Environmental Protection Agency (1970), Webb (pers. comm.).

LAKE NAME: Three (3) lakes
Lake Alice
Lake Dorothy
Lake Maloya
LOCATION: Colorado & New Mexico, USA
SURFACE AREA / MAXIMUM DEPTH:
Lake Alice (0.8 ha) / ---
Lake Dorothy (2.4 ha) / ---
Lake Maloya (32 ha) / 21.3 m

PROBLEM: Overabundance of white suckers *(Catostomus commersonnii)*; excessive turbidity. **RESTORATION OBJECTIVE**: To eliminate the entire fish population and restock with desirable species only. **RESTORATION METHODOLOGY**: Lakes Maloya and Dorothy were treated in Sept., 1961 while Lake Alice was treated in October. In each case, the dosage was 2 mg/l rotenone (7.6% powdered cube root). Application was by boat; the associated streams were also treated. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Dead fish were removed from Lake Maloya only; about 75% (by weight) were white suckers. A significant decrease in turbidity followed each treatment. **REFERENCES**: Harrison (1961).

LAKE NAME: Three (3) ponds
LOCATION: southern Florida, USA
SURFACE AREA: 2020 to 3030 m^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundant macrophytes, including elodea *(Anacharis canadensis)*, coontail *(Ceratophyllum demersum)*, naiad *(Najas* spp.), and pondweeds *(Potamogeton* spp). **RESTORATION OBJECTIVE**: To remove the macrophytes in order to enhance the recreational potential of the ponds. **RESTORATION METHODOLOGY**: Tropical freshwater snails–*Marisa cornavarietis* and *Pomacea australis*–were introduced at a rate of about 19,750/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were eliminated within one year and the ponds maintained in a macrophyte-free condition. *Marisa* also controlled other disease carrying snails by eating their eggs. **REFERENCES**: Agricultural Research (1968).

LAKE NAME: Three (3) ponds
Cecil Jones Pond
James Kimbro Pond
L. B. Golden Pond
LOCATION: Georgia, USA
SURFACE AREA: 1.5 to 2 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundant population of small bluegills *(Lepomis macrochirus)*. **RESTORATION OBJECTIVE**: To evaluate the effect of overwinter drawdown and fish removal by seining upon the fish population. **RESTORATION METHODOLOGY**: The ponds were lowered to 10–25% of their original sizes during October–January; drawdowns were maintained for approximately 80 days. Seining began when the water temperature dropped to 25–26° C. Small bluegills were removed until the catch became too small to justify continued seining; 45 to 172 kg/ha were taken. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Following drawdown and seining, largemouth bass *(Micropterus salmoides)* reproduction increased in each pond; however, definite improvements in the fish population and fishery were noted in only one of the ponds. The lack of greater success in the other two ponds was thought due to inadequate removal of small bluegills and an insufficient population of bluegill predator species (e.g., largemouth bass). **REFERENCES**: Pierce et al. (1963).

LAKE NAME: Three (3) ponds
LOCATION: Mississippi, USA
SURFACE AREA: 3640 to 5670 m^2
MAXIMUM DEPTH: ---

PROBLEM: Presence of undesirable fish species. The ponds were used for raising catfish *(Ictalurus punctatus)*. **RESTORATION OBJECTIVE**: To selectively eliminate the undesirable species. **RESTORATION METHODOLOGY**: Antimycin was applied at concentrations of 5 to 10 μg/l. Treatment costs were $145.79 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: At dosages of 5 and 7.5 μg/l, nearly 99% of the problem species–green sunfish *(Lepomis cyanellus)* and golden shiners *(Notemigonus crysoleucas)*–were eliminated. Subsequent treatment at 10 μg/l further reduced the scalefish population with no apparent effect on the catfish. The treated ponds produced an additional 461 kg of fish worth $507.50. **REFERENCES**: Burress (1968), Burress and Luhning (1969a).

LAKE NAME: Three (3) lakes
Mesa Hill Lake
Nutria Lake
Romah Lake
LOCATION: McKinley Co. & Ocoma Pueblo, New Mexico, USA
SURFACE AREA:
Mesa Hill Lake (20 ha)
Nutria Lake (28 ha)
Romah Lake (101 ha)
MAXIMUM DEPTH:

PROBLEM: Overabundance of macrophytes. **RESTORATION OBJECTIVE**: To reduce the macrophyte growths. To evaluate a potential biological control agent. **RESTORATION METHODOLOGY**: The lakes were stocked with *Orconectes causeyi*, an especially herbivorous species of crayfish. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The degree of macrophyte control was related to the size of the crayfish population and the proximity of a rocky substrate (habitat preferred by the crayfish). The crayfish were effective against *Potamogeton, Myriophyllum, Elodea, Ceratophyllum, Ranunculus, Chara* and filamentous algae but not, *Scirpus, Typha,* and *Polygonum*. **REFERENCES**: Dean (1969).

LAKE NAME: Four (4) reservoirs
Carpenter's Lake*
Dewey Lake*
Herrington Lake
Shanty Hollow
LOCATION: Kentucky, USA
SURFACE AREA / MAXIMUM DEPTH:
Carpenter's Lake (28 ha) / ---
Dewey Lake (4.5 km^2) / ---
Herrington Lake (14.6 km^2) / 79 m
Shanty Hollow (43 ha) / ---

PROBLEM: Overabundant population of undesirable fish species, esp. gizzard shad *(Dorosoma cepedianum)*. **RESTORATION OBJECTIVE**: To selectively remove the undesirable species. **RESTORATION METHODOLOGY**: In Carpenter's, Dewey, and Shanty Hollow reservoirs sufficient 5% rotenone was applied to yield an average concentration of 0.1 mg/l in October, 1954, March, 1955, and April, 1955, respectively. Herrington Lake was first treated in spring, 1956; only part of the lake was treated. Additional treatments were conducted on some of the lakes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The total weight of gizzard shad was drastically reduced in three of the reservoirs and eliminated completely from the fourth. Buffalo *(Ictiobus* spp.) and carp *(Cyprinus carpio)* were also decreased in abundance. There was a subsequent increase in spawning success and survival of largemouth bass *(Micropterus salmoides)* and a definite improvement in fishing success. **REFERENCES**: Smith (1959).

LAKE NAME: Four (4) ponds
Duck*
Jordan*
Massapoag
Wedge
LOCATION: Massachusetts, USA
SURFACE AREA: 8.5 to 21.1 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundant panfish and trashfish. **RESTORATION OBJECTIVE**: To develop methods of increasing the rate of fish removal by netting. Mechanical removal was being used to thin the overabundant populations. **RESTORATION METHODOLOGY**: Copper sulfate was applied to the water in the entire pond, in the immediate vicinity of the netting operations, or around the shoreline. Application occurred in July-August at concentrations ranging from 0.025 to 0.20 mg/l. Two to three low level applications were made in each pond during 1953. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Netting harvest was increased greatly. The higher removal rate lasted for about 24 hours, but could be reinduced by another low level application. All fish species responded to the treatment, but shoreline application was not as effective as either of the other two procedures. In one pond an application of 0.05 mg/l increased the weight removed by 12-fold. The percentage of the population removed was not measured directly but appeared to be significant. **REFERENCES**: Tompkins and Bridges (1958).

LAKE NAME: Four (4) ponds
Middle
Mill
Pleasant
Podunk
LOCATION: Barry Co., Michigan, USA
SURFACE AREA: 32.4 to 81 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundant, slow-growing bluegills *(Lepomis macrochirus)*. **RESTORATION OBJECTIVE**: To eliminate bluegill eggs and fry during the spawning season. To determine the effectiveness of treatment in terms of relative abundance and growth of young-of-the-year bluegills. **RESTORATION METHODOLOGY**: All spawning nests were treated with copper sulfate. Two years of pre-treatment data and four control lakes were used for evaluation of results. Treatment began in May, 1962. One or two 2-man crews were either searching for or treating bluegill nests nearly every day of the spawning season – 18 May to 9 August. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There was no significant effect on the number of young-of-the-year bluegills surviving to the fall. Growth was, however, greatly improved. The mean length averaged 3 and 3.28 cm in fall, 1960 and 1961, respectively; in the fall subsequent to treatment it was 3.61 cm. Nevertheless, the amount of effort required to locate and treat the nests make this control method of doubtful value. **REFERENCES**: Beyerle and Williams (1967).

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*See also the individual listing.

LAKE NAME: Four (4) ponds
Ayers Pond
Bow Lake
Old College Reservoir
Swain's Pond
LOCATION: near Durham, New Hampshire, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundant population of pumpkinseed, *Lepomis gibbosus*. **RESTORATION OBJECTIVE**: To develop a method of selectively destroying panfish nests on all types of lake bottom. **RESTORATION METHODOLOGY**: Compressed pellets of NaOH were introduced into the bottom of the nests. The rate of dispersal and effectiveness were determined but not the concentration. Chemical costs were $0.03 to 0.04 USA/16 nests. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Moderate wave action did not disperse the toxicant too quickly if the nest was at least 0.3 m below the surface. Panfish fry that entered the treated area were killed immediately. Water from abandoned nests was still toxic after two weeks. Eggs and sac-fry were eliminated by treatment. Weekly applications during the spawning season were recommended for adequate panfish control. **REFERENCES**: Jackson (1956).

LAKE NAME: Four (4) lakes
Odland Reservoir
Raleigh Reservoir
South Lake Metigoshe
Wolf Butte Reservoir
LOCATION: North Dakota, USA
SURFACE AREA / MAXIMUM DEPTH:
Odland Reservoir (40 ha) / 4.9 m
Raleigh Reservoir (6.1 ha) / 5.5 m
South Lake Metigoshe (3.7 km^2) / ---
Wolf Butte Reservoir (9.7 ha) / 2.7 m

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To determine the effects of toxaphene on plankton and larger invertebrates during application for fisheries management. **RESTORATION METHODOLOGY**: Concentrations of toxaphene ranged from 5 to 90 μg/l. Treatments occurred during 1960 and 1961. Collections were made before and after treatment. A fifth lake was used as a control. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: No changes in the plankton could definitely be attributed to treatment. No marked reductions were observed among the larger invertebrates. The only exceptions were that *Aphanizomenon* increased after each treatment and the zooplankton was reduced significantly by treatment at 90 μg/l. Fish mortalities ranged from complete to partial. **REFERENCES**: Henegar (1966), Needham (1966).

LAKE NAME: Four (4) lakes
Caldwell Lake
Pine Lake
Steward Hollow Lake
Vesuvius Lake
LOCATION: Ross and Lawrence Cos., Ohio, USA
SURFACE AREA / MAXIMUM DEPTH:
Caldwell Lake (4.0 ha) / 6.0 m
Pine Lake (5.7 ha) / 5.2 m
Steward Hollow Lake (3.2 ha) / 7.5 m
Vesuvius Lake (4.2 ha) / 9.1 m

PROBLEM: Poor quality water in the hypolimnion during the summer. **RESTORATION OBJECTIVE**: To study the effects of artificial destratification on the water quality. **RESTORATION METHODOLOGY**: A 30 cm diameter pump was mounted on a float and anchored over the deepest part of each lake in 1964. The intake was extended to the bottom and the discharge pipe terminated at the water surface. The pump has a capacity of 180 l/sec and was powered by a gasoline engine. At Stewart Hollow Lake, the pump was operated for a period of 20.5 hrs during July and 13.5 hrs in September. Lakes Caldwell and Pine were mixed for 8 and 35 hrs, respectively, during August. The pump was operated for 208 hrs at Vesuvius Lake during September. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The pump successfully destratified all four lakes; pre-existing gradients for temperature, pH, dissolved oxygen, carbon dioxide, and plankton were eliminated by pumping. Although the usual fall bloom of blue-green algae did not occur in 1964 in any of the lakes, the total number of algae did not decline. All of the lakes except Pine showed a tendency to restratify after mixing ceased. **REFERENCES**: Irwin et al. (1966), Symons et al. (1970).

LAKE NAME: Five (5) farm ponds
LOCATION: Auburn Univ., Auburn, Alabama, USA
SURFACE AREA: 1 to 10.3 ha
MAXIMUM DEPTH: ---

PROBLEM: Nuisance algal blooms, esp. *Microcystis*. **RESTORATION OBJECTIVE**: To control the algae with low concentrations of copper sulfate and to determine the effects of treatment upon zooplankton abundance. **RESTORATION METHODOLOGY**: Copper sulfate was applied at rates of about 0.8 to 1.0 kg/ha (0.05 to 0.08 mg/l) between 27 July and 15 November, 1957. Crystalline copper sulfate was placed in bags and submerged in the pond at a depth of approximately 15.2 cm. Distribution occurred by natural wave action. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment significantly decreased *Microcystis* abundance. There was an inverse relationship between the abundance of *Microcystis* and the number of zooplankters; therefore, the zooplankton usually increased within a few days after application of copper sulfate. The danger of fishkills from low dissolved oxygen levels associated with the algal die-offs was apparently reduced at dosages near 0.84 kg/ha. **REFERENCES**: Crance (1963).

LAKE NAME: Five (5) lakes
Barbour
Coffee
Crenshaw
Cullman
Pike
LOCATION: Alabama, USA
SURFACE AREA:
Barbour (30 ha)
Coffee (32 ha)
Crenshaw (21 ha)
Cullman (13 ha)
Pike (18 ha)
MAXIMUM DEPTH: ---

PROBLEM: Overcrowded panfish; unbalanced fish population; poor sport fishery. **RESTORATION OBJECTIVE**: To improve the fish population characteristics using a piscicide. **RESTORATION METHODOLOGY**: Partial fishkills were implemented with rotenone during 1952–58. Cube powder and liquid emulsifiable formulations (both about 5% rotenone) were used. In some cases the littoral zone (up to 0.9–1.2 m deep) was treated; three to seven applications of about 1 kg of 5% rotenone/100 m of shoreline at three to five day intervals. In other instances a certain percentage of the lake was treated at approximately 1 mg/l; the toxicant was sprayed on the surface and applied directly to the bottom waters. In at least one instance the waters were later detoxified using $KMnO_4$. Fingerling bass *(Micropterus salmoides)* were then stocked at a rate of 62–494/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Greatest success resulted from treatments during September–November. About 90 to 170 kg/ha of intermediate–sized panfish had to be killed in order to restore population balance; however, results were unsatisfactory when bullheads *(Ictalurus* spp.) and crappie *(Pomoxis* spp.) were present. During the years of population balance an average of 217 kg/ha were harvested annually in the sport fishery while only 149 kg/ha were removed during the years of imbalance. **REFERENCES**: Hooper and Crance (1960).

LAKE NAME: Six (6) ponds
LOCATION: near Auburn, Alabama, USA
SURFACE AREA: 1010 m^2 each
MAXIMUM DEPTH: ---

PROBLEM: Excessive growths of filamentous algae and submerged macrophytes. Inhibited fish production. **RESTORATION OBJECTIVE**: To determine the effectiveness of sodium arsenite as a control agent for *Pithophora* and to study the effects of repeated applications of sodium arsenite at 4 and 8 mg/l on the benthos and fish. **RESTORATION METHODOLOGY**: Sodium arsenite was injected below the surface from a boat. An attempt was made to achieve an even distribution; various dosages were involved. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Satisfactory control of *Pithophora* was usually achieved with one or more applications at 4 mg/l, providing the algae was in an actively growing stage. Two applications, one month apart, at 4 mg/l reduced benthos abundance and bluegill *(Lepomis macrochirus)* production by an average of 34 and 42%, respectively, whereas at 8 mg/l they were decreased by 45 and 56%, respectively. Other studies indicated that delayed bluegill reproduction and poor growth of largemouth bass *(Micropterus salmoides)* occurred following treatment. **REFERENCES**: Lawrence (1958).

LAKE NAME: Six (6) ponds
Biggers Reynolds
Henry Slaughter
Hill Todd
LOCATION: west central Georgia, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundant population of panfish; poor fishing quality. **RESTORATION OBJECTIVE**: To selectively remove the problem species, especially bluegills *(Lepomis macrochirus)*. To determine the effectiveness of low dosages of a piscicide. **RESTORATION METHODOLOGY**: Antimycin was applied during 1966–67 at concentrations of 0.4 to 1.0 µg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: At 0.4 g/l only bluegills were killed in two of the ponds, 30% of the population up to 10.2 cm in length (water temperatures of 8.9 to 16.7° C); however, in a third pond several other species were also killed (water temperature of 23.9° C). At 0.6 µg/l in two ponds 48% of the bluegills below 10.2 cm were killed plus 3% of the larger bluegills and 5% of the largemouth bass *(Micropterus salmoides)* under 15.2 cm; in a third pond about 90% of the bluegills and 35% of the largemouth bass of all sizes were eradicated. At 0.8 µg/l in three ponds almost all of the bluegills were eliminated, 79 to 92% of the largemouth bass below 15.2 cm, and 12 to 13% of the larger bass. At 1.0 µg/l the mortality consisted of nearly all of the bluegills, 95% of the small bass, and 79% of the large bass. Surviving adults were able to spawn successfully. The chemical cost for treating 1233.5 m^3 of water at 0.4 µg/l was $0.64 USA. **REFERENCES**: Burress (1968), Burress and Luhning (1969b).

LAKE NAME: Six (6) lakes
LOCATION: Pennsylvania, USA
SURFACE AREA: 69 ha to 1.7 km^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of macrophytes–emergents and submergents. **RESTORATION OBJECTIVE**: To evaluate the use of herbicides for controlling macrophytes. **RESTORATION METHODOLOGY**: Diquat, kuron, and Aquathol Plus were applied to one-third or less of each lake in 1969. A seventh lake was not treated and served as a control. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: No persistent, adverse ecological consequences were observed; however, reductions in dissolved oxygen and phytoplankton of up to 44 and 95%, respectively, were measured after treatment. Diquat applied at a rate of 2.8 to 11.7 l/ha was highly successful in providing seasonal control of *Potamogeton crispus, P. Natans,* and *P. epihydrus.* Kuron, when used at a rate of 6 to 12.2 l/ha in at least two successive treatments, three months apart achieved 90% control of *Nuphar, Nymphaea,* and *Brasenia.* The use of Aquathol Plus at a rate of 27.1 l/ha was successful in controlling *Myriophyllum humile, Utricularia purpurea, Nuphar variegatum,* and *Brasenia schreberi* for two seasons in a softwater lake. **REFERENCES**: Barker (1972).

LAKE NAME: Seven (7) ponds
LOCATION: Kennebec Co., Maine, USA
SURFACE AREA: 2.4 to 11.7 ha
MAXIMUM DEPTH: 7.3 to 21.3 m

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To eliminate the undesirable fish species. **RESTORATION METHODOLOGY**: During the summer of 1951, the ponds were treated with Noxfish (5%

emulsifiable rotenone) and Fish-Tox. Most of the ponds received 0.55 mg/l. Application was by boat (surface spraying and underwater injection). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Complete kills occurred in five of the seven ponds. Surface application of Noxfish penetrated to 4.6 m only; the thermocline acted as a barrier against deeper penetration. Most of the ponds remained toxic for 2–3 months. **REFERENCES**: Foye (1956).

LAKE NAME: Eight (8) ponds
LOCATION: Georgia, USA
SURFACE AREA: 8100 m^2 to 7.7 ha
MAXIMUM DEPTH: ---

PROBLEM: Undesirable characteristics of the fish population; overabundant, small panfish; and poor fishing quality. **RESTORATION OBJECTIVE**: To improve the sport fishery. **RESTORATION METHODOLOGY**: Several management techniques were applied, including partial poisoning using rotenone, stocking of predator fish, overwinter drawdown, and mechanical removal of the problem species. Stocking ranged from about 250 to 500 largemouth bass *(Micropterus salmoides)* fingerlings/ha; removal of the problem species varied from 41 to 170 kg/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results ranged from no effect to definite improvement; there were no obvious cause-and-effect relationships. Large population reductions and overwinter drawdown were sometimes effective but results were erratic. The stocking programs appeared to have little value. Conclusions were: (1) a certain weight removal was not as important as the size of the remaining population, (2) population reduction without the presence or addition of effective predators (e.g., adult bass) produced only temporary improvement, and (3) the length of time to re-establish a balanced population in successful projects varied from one to three years after treatment. The results of these eight ponds were considered typical of similar projects on many other ponds in Georgia. **REFERENCES**: Thomaston (1962).

LAKE NAME: Eight (8) ponds
LOCATION: Georgia & Mississippi, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of undesirable fish species. **RESTORATION OBJECTIVE**: To selectively reduce the populations of problem species. **RESTORATION METHODOLOGY**: In August, 1967 panfish nests were treated with antimycin. The piscicide was applied above the nests in 20 to 61 cm deep water. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After three hours the nests were abandoned; the eggs did not hatch. **REFERENCES**: Burress (1968).

LAKE NAME: Eight (8) ponds
LOCATION: northern New Jersey, USA
SURFACE AREA: 2020 m^2 to 2 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundant macrophytes. Similar problem conditions exist in many other waters in the region. **RESTORATION OBJECTIVE**: To control several species of macrophytes using different concentrations of Kuron (active ingredient, silvex). **RESTORATION METHODOLOGY**: Kuron was applied by spraying to yield concentrations of 0.5 to 2.5 mg/l. On one occasion the concentration was 3.5 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Concentrations of 0.5 mg/l were only effective on the white waterlily, *Nymphaea odorata*. The submerged species were not affected. At 1 mg/l good control was obtained for waterweed *(Anacharis* sp.), yellow waterlily *(Nuphar* sp.), and mud plantain *(Heteranthea* sp.). Complete control of water milfoil *(Myriophyllum)* and bladderwort *(Utricularia)* was achieved by using concentrations of 2 and 2.5 mg/l. Pondweed *(Potamogeton)* were not controlled at any of the concentrations. **REFERENCES**: Younger (1958).

LAKE NAME: Nine (9) ponds
LOCATION: near Denver, Colorado and Tishomingo, Oklahoma, USA
SURFACE AREA: 405 to 2710 m^2
MAXIMUM DEPTH: 0.9 to 3.4 m

PROBLEM: Overabundant vegetation, macrophytes and algae. **RESTORATION OBJECTIVE**: To determine the vegetation control effectiveness of dichlobenil and to study the ecological consequences of its application. **RESTORATION METHODOLOGY**: Eight ponds were treated with dichlobenil (50% wettable powder) on 5 June, 1964; the concentrations ranged from 10 to 40 mg/l. Dichlobenil (4% granular) was applied to the ninth pond on 29 April, 1964 at 0.58 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: At 0.58 mg/l the vegetation was affected soon after treatment; *Chara* was effectively controlled; and the growth of filamentous algae was retarded, although some regrowth occurred after three months. At 10 mg/l the vegetation was completely eliminated in one pond; however, some regrowth of *Chara* was noted by September in the other treated pond. At 20 mg/l excellent control of all vegetation was achieved except that *Chara* (10.2 to 15.2 cm tall) was present on 75% of the bottom by September. Ponds treated at 40 mg/l were completely devoid of vegetation in September. Bluegill survival varied directly with the dichlobenil concentration. From late May to 25 September the survival was: 60% in some untreated ponds; 20–25% in the ponds treated at 10 mg/l; 5–8%, at 20 mg/l; and 2–4%, at 40 mg/l. **REFERENCES**: Cope et al. (1969).

LAKE NAME: Nine (9) ponds and lakes
LOCATION: Georgia, USA
SURFACE AREA: 1 ha to 2 km^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundant population of small bluegills *(Lepomis macrochirus)*. **RESTORATION OBJECTIVE**: To determine the effect of overwinter drawdown upon the fish population. **RESTORATION METHODOLOGY**: During October–January the ponds were lowered to 25–75% of their original sizes. Drawdown was maintained for approximately 80 days. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Following drawdown the typical effects were: (1) decreased numbers of small bluegills, (2) increased largemouth bass *(Micropterus salmoides)* reproduction, (3) increased bluegill reproduction, and (4) some improvement in the bluegill population or sport fishery. The greatest improvement occurred in ponds with high largemouth bass populations and no forage species other than small bluegills. **REFERENCES**: Pierce et al. (1963).

LAKE NAME: Nine (9) lakes
LOCATION: central Wisconsin, USA
SURFACE AREA: 7.7 ha to 10.6 km^2
MAXIMUM DEPTH: 1.2 to 18 m

PROBLEM: Variety of fish population problems. **RESTORATION OBJECTIVE**: To improve the management of these lakes through the use of a piscicide. To study the overall effects of toxaphene usage. **RESTORATION METHODOLOGY**: Toxaphene was used during 1957–66 for selective, partial, or total removal of the fish population. Concentrations ranged from 0.005 to 0.42 mg/l with 0.1 mg/l the most common. In some cases several applications occurred in a single year. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Toxaphene was an effective toxicant, although results were somewhat dependent on the existing conditions. Thorough dispersal was essential. Effectiveness was limited in very turbid waters due to sorption on the particulate matter. Residues were persistent, but detoxification was enhanced in warm, fertile, alkaline lakes. Plankton, mollusks, fish, and birds were capable of accumulating large quantities of toxaphene with a wide variation in effect. **REFERENCES**: Hughes (1968).

LAKE NAME: Ten (10) lakes and reservoirs

LOCATION: Oregon, USA

SURFACE AREA: 1.6 ha to 6.1 km^2

MAXIMUM DEPTH: 1.8 to 44.9 m

PROBLEM: Undesirable characteristics of the fish population **RESTORATION OBJECTIVE**: To eliminate the entire fish population and restock. **RESTORATION METHODOLOGY**: Toxaphene was applied to the surface by boat and airplane. The concentrations ranged from 0.01 to 0.1 mg/l. The tributaries were treated with liquid 5% rotenone, liquid synergized rotenone, and/or toxaphene. Treatments occurred during 1958 and 1959. The average cost of treatment with toxaphene was $0.29 USA/1000 m^3 of water. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A complete kill resulted from six of the treatments; a concentration of 0.032 to 0.04 mg/l appeared optimal. Detoxification occurred more rapidly in large, shallow waters and ranged from two to over 30 months. Angler success was good the season after restocking. **REFERENCES**: Borovicka (1961).

LAKE NAME: Thirteen (13) ponds

LOCATION: near Davis, California, USA

SURFACE AREA: 2000 m^2 to 1 ha

MAXIMUM DEPTH: 0.6 to 2.4 m

PROBLEM: Overabundant macrophytes and algae. **RESTORATION OBJECTIVE**: To determine the effect of endothall on vegetation and fish. **RESTORATION METHODOLOGY**: Endothall was applied by boat to yield concentrations of 0.1, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.4, 1.7, 1.8, 1.9, 2.0 and 3.0 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: American pondweed *(Potamogeton nodosus)*, sago pondweed, *(P. pectinatus)*, curlyleaf pondweed *(P. crispus)*, leafy pondweed *(P. foliosus)*, small pondweed *(P. pusillus)*, horned pondweed *(Zannichellia polustris)*, southern naiad, *(Najas guadalupensis)*, and common coontail *(Ceratophyllum demersum)* were controlled by endothall. However, it was ineffective against American elodea *(Elodea canadensis)*, duckweed *(Lemna)*, nitella *(Nitella clavata)*, and chara *(Chara vulgaris)*. After elimination of the other species, American elodea rapidly spread to infest the entire reservoir in one instance. Fishkills were not observed during or after treatments. Endothall dissipated rapidly; initial concentrations of 1.4, 0.7, and 0.3 mg/l were reduced to 0.0 mg/l in 12, 8 and 20 days, respectively. No single water quality factor appeared to influence the dissipation rate. **REFERENCES**: Yeo (1970).

LAKE NAME: Fourteen (14) lakes

LOCATION: southern Minnesota, USA

SURFACE AREA: 92 ha to 15.4 km^2

MAXIMUM DEPTH: --

PROBLEM: Presence of undesirable fish species. **RESTORATION OBJECTIVE**: To control the population of trashfish through annual removal. **RESTORATION METHODOLOGY**: The average harvest of trashfish ranged from 41 to 213 kg/ha for the 14 lakes over a 25–year period. The fish were removed by netting; the records were incomplete for some years. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In the five lakes with nearly complete harvest records, no trends in the catch were evident. The growth each year apparently compensated for the amount removed. Comparison of the average annual harvest, using all available years for the 14 lakes, with the average standing crop in 40 other nonharvested trashfish lakes suggested that the annual removal was about one-third of the catchable population. **REFERENCES**: Moyle et al. (1950).

LAKE NAME: Fifteen (15) lakes

LOCATION: Michigan, USA

SURFACE AREA: --

MAXIMUM DEPTH: --

PROBLEM: Slow-growing bluegills *(Lepomis macrochirus)*. **RESTORATION OBJECTIVE**: To determine the effect of various degrees of population reduction upon the rate of growth for the remaining bluegills. **RESTORATION METHODOLOGY**: The lakes were treated with rotenone between 1956 and 1959. In 1956 the cost was $20-25 USA/ha, mostly for manpower to remove the dead fish. The estimated percentage kill was 20% in one lake, 20-40% in four lakes, 40-60% in three lakes, 60-80% in one lake, 80-95% in three lakes, and 100% in four lakes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The year after treatment the annual growth increment for one-year-old bluegills was 2.54, 3.56, 5.08, 5.59, 7.62 and 9.15 cm for the treatments in the order of increasing percentage removal. The growth increment for three-year-old bluegills during the third year after treatment still tended to be higher for the highest removal rates, but the difference was on the order of only 1.27 cm. Differences in management (e.g., predator stocking and fishing regulations) existed between the lakes after treatment; however, the information suggested that these did not significantly influence the growth rates. **REFERENCES**: Hooper et al. (1964).

LAKE NAME: Sixteen (16) lakes

LOCATION: North Dakota, USA

SURFACE AREA: 2.6 ha to 3.7 km^2

MAXIMUM DEPTH: 2.4 to 7.9 m

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To determine the lower lethal limit of toxaphene to fish in the surface waters of the region. **RESTORATION METHODOLOGY**: Concentrations of toxaphene ranged from 5 to 35 μg/l. Treatments occurred during 1959 and 1960. Physical and chemical studies were made and test netting was carried out before and after treatment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Mortality varied from incomplete to complete. Size of the fish killed was related to the concentration of piscicide; as the dosage increased so did the fish size. The lower lethal concentration for total mortality was 25 μg/l. There was no definite relationship between water chemistry and the rate of fish toxicity, although reaction was slowed by low temperatures. Five of the seven lakes experiencing a total kill detoxified within seven months. Increased water clarity resulted from each application; this was either due to the removal of fish that cause turbidity, or more probably to the limited flocculation caused by treatment with toxaphene. **REFERENCES**: Henegar (1966).

LAKE NAME: Eighteen (18) ponds

LOCATION: Oklahoma, USA

SURFACE AREA: 1000 m^2 to 1.7 ha

MAXIMUM DEPTH: 1.8 to 4 m

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To eradicate the entire fish population using rotenone. **RESTORATION METHODOLOGY**: The concentrations of rotenone ranged from 0.5 to 3.5 mg/l. The treatments occurred in 1951. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Complete elimination was achieved on only two ponds and in one case, only after a second treatment at 2 mg/l (the first treatment was at 1 mg/l). The findings were: (1) rotenone must be applied directly into the bottom waters in a thermally stratified pond, (2) detoxification occurred more rapidly at high alkalinities (60–284 mg/l) than at low ones, (3) detoxification at high alkalinities occurred more rapidly in clear ponds than in turbid ones, and (4) cold temperatures slowed the rate of detoxification. In 15 of the 16 ponds exhibiting an incomplete kill only young-of-the-year were subsequently found alive, indicating the survival of eggs and/or fry. **REFERENCES**: Clemens and Martin (1952).

LAKE NAME: Twenty (20) ponds and lakes

LOCATION: Arkansas, Nebraska, New York, New Hampshire, Wyoming, and Wisconsin, USA

SURFACE AREA: 1010 m^2 to 25.5 ha

MAXIMUM DEPTH: ---

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To evaluate antimycin as a piscicide under various limnological conditions. To determine the effect of treatment at several concentrations. **RESTORATION METHODOLOGY**: Antimycin was used in concentrations ranging from 0.13 to 12 μg/l. Liquid and granular formulations were tested. Applications were conducted during 1964–66. The rate of detoxification was measured by in-situ bioassay. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The quantity of piscicide needed for effective treatment increased with a rise in pH or hardness, or a drop in water temperature. Problem species such as carp *(Cyprinus carpio)* and suckers *(Catostomus* spp.) were eliminated by 3 to 10 μg/l, depending on the limnological conditions. Other problem species were more resistant. Carp began to show distress in 10 to 24 hrs with mortality complete within 72 to 96 hrs; antimycin effects appeared to be irreversible. Fish did not actively avoid the treated areas. Fish eggs were killed at the same concentrations effective against older individuals of a species. In most waters detoxification occurred within two weeks; $KMnO_4$ could be used to detoxify antimycin. Other aquatic organisms were mostly unaffected at the concentrations used. **REFERENCES**: Gilderhus et al. (1969).

LAKE NAME: Twenty-one (21) lakes

LOCATION: Pennsylvania, USA

SURFACE AREA: 2.8 ha to 6.7 km^2

MAXIMUM DEPTH: ---

PROBLEM: Nuisance algal blooms and excessive macrophyte growths. **RESTORATION OBJECTIVE**: To alleviate the vegetation problems in order to enhance the recreational usage of each lake. **RESTORATION METHODOLOGY**: Herbicides were applied to the areas of greatest vegetation abundance. The herbicide costs were about $50.70 USA/ha in 1972. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Macrophyte control was achieved. Treatment methodology is now being refined in order to maximize control while minimizing both cost and ecological disturbance. **REFERENCES**: Maurer (pers. comm.; information on specific lake treatments is available).

LAKE NAME: Twenty-six (26) farm ponds

LOCATION: Stuttgart, Arkansas, USA

SURFACE AREA: 400 to 4000 m^2

MAXIMUM DEPTH: ---

PROBLEM: Nuisance algal blooms. **RESTORATION OBJECTIVE**: To control the algal blooms using karmex. To study the effect of treatment on the fish and invertebrates. **RESTORATION METHODOLOGY**: Karmex (diuron) was applied to the surface of each pond between 15 April and 1 June, 1964. The resultant concentrations ranged from 0.05 to 0.38 mg/l (0.56 to 3.4 kg/ha). The chemical cost was $8.65 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: At the time of treatment, all of the ponds were infested with filamentous algae *(Spirogyra, Oedegonium, Cladophora,* and *Pithophora).* All of these species except *Pithophora* were eliminated at each of the treatment levels. *Pithophora* was not cleared from every pond treated at 0.56 kg/ha. All of the other ponds became free of filamentous algae and remained so until 1 September, 1964 (16 weeks). *Najas* sp. was initially present in the ponds treated at 0.84 and 1.12 kg/ha; however, the growths were eliminated by treatment and no regrowth occurred. Phytoplankton was also eliminated from all of the ponds, but in all instances blooms reappeared within 2–4 weeks. Differences in response were attributed to the different treatment levels since regrowth was slowest at the highest dosage of karmex. Treatment had no detectable effect upon the zooplankton, benthos, or fish. **REFERENCES**: Sills (1964).

LAKE NAME: Twenty-six (26) lakes

LOCATION: North Dakota, USA

SURFACE AREA: 3.2 ha to 6.7 km^2

MAXIMUM DEPTH: 2.1 to 14 m

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To eliminate the entire fish population. **RESTORATION METHODOLOGY**: The lakes were treated with rotenone and/or toxaphene during 1951–58; Fish-Tox, Pro-Noxfish, and Chem-Fish were used. The dosages ranged from 0.5 to 3 mg/l, 0.4 to 2 mg/l, and 1.2 to 1.5 mg/l for Fish-Tox, Pro-Noxfish, and Chem-Fish, respectively. The costs varied from $0.40 to $2.23 USA/1000 m^3 for Fish-Tox; $0.51 to $3.51/1000 m^3 for Pro-Noxfish; and $1.15 to $1.81/1000 m^3 for Chem-Fish. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The golden shiner *(Notemigonus crysoleucas),* common sucker *(Catostomus commersonnii),* and black bullhead *(Ictalurus melas)* were the most resistant species to rotenone; 3 mg/l were necessary to eliminate the bullheads. The only complete kills occurred during toxaphene usage (12 of 13 attempts). The necessary dosage of toxaphene increased with higher values of pH, hardness, and turbidity. Most lakes in the area could effectively be treated at 60 to 125 μg/l toxaphene. **REFERENCES**: Henegar (1958).

LAKE NAME: Over twenty-six (26) lakes
LOCATION: Michigan and Wisconsin, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundant growths of a wide variety of macrophytes. **RESTORATION OBJECTIVE**: To harvest the problem macrophytes in order to remove nutrients and make the lake more usable. To evaluate the effectiveness of each control program by interviewing the people responsible for its operation. **RESTORATION METHODOLOGY**: Mechanical harvesting was conducted during the growing season. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In most cases (17), harvesting was thought to yield short-term benefits. In general, the lakes became more usable the year after harvesting. Continued harvesting was felt to produce long-term benefits by six of the operators. In a few cases the effects of harvesting were considered detrimental. **REFERENCES**: Nichols (1974).

LAKE NAME: Twenty-seven (27) lakes
LOCATION: Michigan, USA
SURFACE AREA: 6100 m^2 to 4.2 km^2
MAXIMUM DEPTH: ---

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To improve the fish population dynamics by either partial or complete eradication using toxaphene (Coopertox No. 6). **RESTORATION METHODOLOGY**: Toxaphene was applied by boat to the lake surface and/or underwater in concentrations from 2 to 100 µg/l. A variety of lake types were treated between 1954 and 1958. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Preliminary conclusions for achieving complete kills in lakes ranging in size from 8.1 to 81 ha were: (1) shallow, unstratified, highly turbid warmwater lakes require dosages of 30 to 50 µg/l; (2) shallow, unstratified, moderately turbid, highly productive lakes require dosages of 20 to 30 µg/l; and (3) stratified lakes of moderate depth and moderate to low transparency require dosages of 15 to 20 µg/l. Categories 1 and 2 would detoxify in less than 3 months while category 3 would take up to 6 months. Concentrations of 2 to 7 µg/l were used in partial poisoning projects. The best concentration apparently was 5 µg/l for small, slow-growing fish; however, further testing was needed, especially within the 2 to 5 µg/l range. **REFERENCES**: Hooper and Fukano (1960).

LAKE NAME: About fifty (50) lakes and ponds
LOCATION: Canada, Guatamala, and USA (19 states)
SURFACE AREA: 81 m^2 to 2 km^2
MAXIMUM DEPTH: ---

PROBLEM: Variety of fish population problems. **RESTORATION OBJECTIVE**: To improve the fish population characteristics. To study the effect of antimycin A under a wide range of environmental conditions and types of application. **RESTORATION METHODOLOGY**: Several formulations were employed during 1963–67, including antimycin coated on sand particles (Fintrol-5, -15 and -30). It was used for partial reclamations and as a general or selective piscicide. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: It was effective in acid and alkaline waters at cold and warm temperatures. The formulations contributed no color or odor to the water and did not repel fish. The toxic action-respiratory inhibition–was irreversible in most fishes. Fish killing concentrations were harmless to most aquatic invertebrates and to higher vertebrates. **REFERENCES**: Lennon and Berger (1970).

LAKE NAME: Fifty-six (56) farm ponds
LOCATION: Kentucky, USA
SURFACE AREA: ---
MAXIMUM DEPTH: 1.5 to 5.5 m

PROBLEM: Undesirable fish population characteristics. Minimal information available concerning piscicide usage. **RESTORATION OBJECTIVE**: To determine the best rotenone formulation to use for total fish eradication under various seasonal conditions. **RESTORATION METHODOLOGY**: Four rotenone compounds (Pro-Noxfish, Chem-Fish Regular, Chem-Fish Special, and 5% rotenone powdered cube) were used at a concentration of 1 mg/l during 1956–58. The toxicant was sprayed on the lake surface. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Powdered cube was used in five ponds during the summer with complete eradication. Pro-Noxfish was used in 12 ponds during the summer with complete success in 11 ponds; 18 ponds were treated in the fall with complete eradication in 12 ponds. Chem-Fish Regular was applied to seven ponds during the summer with complete success. Chem-Fish Special was used in 14 ponds during the fall with complete success in 11 instances; heavy rainfall interfered with 2 of the treatments. Rotenone, in lethal concentrations, penetrated to 2.4 m regardless of the prevailing water conditions; this was one reason summer treatments were more effective (there was an oxygen deficit in the bottom waters during this season). The yellow bullhead (*Ictalurus natalus*) was the most resistant species. **REFERENCES**: Turner (1959).

LAKE NAME: Eighty-four (84) lakes
LOCATION: Michigan, USA
SURFACE AREA: 1600 m^2 to 2.2 km^2
MAXIMUM DEPTH: 1.2 to 25.9 m

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To evaluate the results of attempted complete fish eradication using the piscicide, rotenone. **RESTORATION METHODOLOGY**: The rotenone dosages ranged from 0.5 to 10 mg/l. The evaluation included only those lakes that were test netted after treatment. The treatments occurred during 1957–67. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Thirty-four lakes were found to have complete kills. The apparent optimal conditions necessary for a complete kill using rotenone were: (1) emulsifiable rotenone at a concentration of at least 1.5 mg/l, (2) water temperature of 15.5 to 20.5° C, (3) lake size of less than 8.1 ha, (4) maximum depth of 3.4 to 6.1 m, (5) shallows comprising 60 to 80% of the total volume, (6) alkalinity of 150 to 200 mg/l, (7) pH of 8.0 or less, (8) minimum of marshes, dense weed beds, floating bogs, turbidity, springs, and soft bottom areas, and (9) correct application methodology. **REFERENCES**: Spitler (1970).

LAKE NAME: Over one thousand (1000) lakes
LOCATION: USA (nationwide)
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Excessive eutrophication. The extent of the eutrophication problem is poorly defined nationwide. There is a definite need for more information in order to develop a national phosphate policy. **RESTORATION OBJECTIVE**: To determine those lakes which will benefit from upgraded municipal sewage treatment plants, particularly with regard to phosphate removal. **RESTORATION METHODOLOGY**: Wherever warranted, municipal sewage treatment plants will be upgraded through federal assistance. A nationwide lake survey is now underway. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The survey has already investigated about 250 lakes in Minnesota, Wisconsin, Michigan, New York, and the New England states. During 1973 about 300 lakes will be sampled in the remaining eastern states; lakes in the western states will be surveyed in later years. The program is scheduled for completion by 1977. **REFERENCES**: American Chemical Society (1973b), Office of Research and Monitoring, U. S. Environmental Protection Agency (1972), Payne (pers. comm.), Thomas (pers. comm.).

LAKE NAME: 1860 Reservoir

LOCATION: Wethersfield, Connecticut, USA
SURFACE AREA: 13.4 ha
MAXIMUM DEPTH: 1.2 m

PROBLEM: Nuisance growth of macrophytes. **RESTORATION OBJECTIVE**: To obtain a broad spectrum chemical control agent. **RESTORATION METHODOLOGY**: Simazine was applied at 1.9 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were eliminated after 4–6 weeks and the lake remained essentially macrophyte-free during the rest of the growing season. Simazine residue analyses are still being conducted for the water and sediment samples. **REFERENCES**: Ahrens (pers. comm.), Ahrens and Block (1972).

LAKE NAME: Alanconnie Lake

LOCATION: southwestern Pennsylvania, USA
SURFACE AREA: 4.1 ha
MAXIMUM DEPTH: 2.7 m

PROBLEM: Overabundant, slow-growing panfish. **RESTORATION OBJECTIVE**: To exert heavy exploitation upon a mixed fish population in order to evaluate the response of individual species to this management technique. **RESTORATION METHODOLOGY**: Population estimates were made each spring, 1962–69. In 1962 71% of the total population was removed by treating two-thirds of the lake with rotenone. In subsequent years the fish were removed by netting; exploitation ranged from 34 to 71% annually. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The total number of fish present remained high until 1966 when a sharp decrease began; however, this change was thought primarily due to increased siltation, turbidity, and introduction of carp *(Cyprinus carpio)* from an upstream reservoir in 1966. High exploitation in 1962 resulted in increased reproduction and high initial survival of the 1962 year-class for most species. Prior to 1966 as the total population was reduced, most species responded by increased growth. In 1962 the fish density was 48.7 kg/ha; bluegill *(Lepomis macrochirus)* growth did not improve until this total fish density was dropped below 20 kg/ha. There was poor correlation between exploitation rate and either growth or condition when analyzed on an individual species basis, but the collective response was more predictable. **REFERENCES**: Cooper et al. (1971).

LAKE NAME: Lake Alice

LOCATION: University of Florida, Alachua Co., Florida, USA
SURFACE AREA: 35 ha (incl. marsh)
MAXIMUM DEPTH: 4.3 m

PROBLEM: Most of surface covered with water hyacinths *(Eichornia crassipes)*. Influx of sewage treatment plant effluent. **RESTORATION OBJECTIVE**: To keep the water hyacinths under control. **RESTORATION METHODOLOGY**: In 1970 the water hyacinths were removed by air boat and a specially designed dredge. In the future the effluent from the sewage treatment plant will be diverted to another disposal area (probable five year project). Pre-treatment investigations are now underway concerning data requirements for water quality models. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Macrophyte harvesting removed an estimated 150 kg P/ha from the lake. There was an improvement in the biotic community, esp. the fish population, although submergents began to proliferate (mainly *Ceratophyllum demersum)*. **REFERENCES**: Brezonik (pers. comm.), Lake (pers. comm.).

LAKE NAME: Allen

LOCATION: Hardin Co., Ohio, USA
SURFACE AREA: 1.1 ha
MAXIMUM DEPTH: --

PROBLEM: Overabundant, slow-growing bluegills *(Lepomis macrochirus)*; insufficient numbers of desirable species. **RESTORATION OBJECTIVE**: To develop a simple, selective, and inexpensive method of bluegill population control. **RESTORATION METHODOLOGY**: Copper sulfate was applied to spawning beds to accomplish nest destruction. Four areas consisting of at least 50 nests each were chosen for study; two were treated and two were used as controls. Approximately 6 g were applied to each nest in large crystal form. The nests were treated on 30 June, 1936 during peak spawning activity. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The water was quiet and the $CuSO_4$ remained concentrated in the nests for over 15 minutes. The adult bluegills were irritated by the chemical, but initially they fanned the nests violently. After 4 hrs the adults abandoned the treatment areas and made no attempt to return during the following month. The concentration was estimated to be 101 mg/l prior to dilution. This concentration was more than sufficient to be lethal for the eggs and fry. The two control areas produced successful hatches of bluegill eggs. **REFERENCES**: Allison (undated).

LAKE NAME: Alma

LOCATION: Vinton Co., Ohio, USA
SURFACE AREA: 29 ha
MAXIMUM DEPTH: --

PROBLEM: Restricted sport fishery. Unknown value of fishing regulations. **RESTORATION OBJECTIVE**: To determine the effect of liberalized fishing restrictions on the sport fishery and fish population. **RESTORATION METHODOLOGY**: Liberalized fishing was initiated in 1945. A continual daily creel census and periodic fyke net sampling were used to measure the results. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During 1945–47, 11.2 to 22.4 kg/ha were removed each year. The catch rate (fish/hr) was the same or lower after liberalization. A 20 and six fish daily bag limit would have affected less than 3% of the bluegill *(Lepomis macrochirus)* fishermen and 1% of the largemouth bass *(Micropterus salmoides)* fishermen, respectively. There was no measurable difference in fish populations or in angler's success that could be related to the liberalized fishing. **REFERENCES**: Pelton (1948).

LAKE NAME: Lake Almanor

LOCATION: Plumas Co., California, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Deteriorated sport fishery; overabundant carp *(Cyprinus carpio)* population. **RESTORATION OBJECTIVE:** To selectively remove the problem species. **RESTORATION METHODOLOGY:** In fall, 1940 a trap was constructed to catch the carp during their spawning migration. Rotenone compounds were also applied to select areas of the lake during spawning activity. Typically a high concentration "barrier" was created across the opening of a bay or cove before complete treatment. Actual concentrations were not determined. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** High water levels severely reduced the effectiveness of the trap; most of the carp escaped by swimming around it. In 1941, an estimated 10,000 to 12,000 carp were killed by rotenone treatments. After detoxification carp reentered the areas and treatment could be repeated successfully. Few fish of other species were observed among the dead. Other observations included: (1) 50–75% of the carp eggs became fungused and died, and (2) few immature carp were found in the treated areas. **REFERENCES:** Wales (1942).

LAKE NAME: Anacoco Lake

LOCATION: Leesville, Louisiana, USA
SURFACE AREA: 10.5 km^2
MAXIMUM DEPTH: (mean depth, 2.8 m)

PROBLEM: Noxious macrophyte growths and undesirable fish population characteristics. **RESTORATION OBJECTIVE:** To determine the effect of water level fluctuations (drawdown) on the limnological conditions. **RESTORATION METHODOLOGY:** Drawdown occurred 1961 through 1964. Each year the water level was dropped 1.5 m starting about 5 July (surface area reduced by 50%). Drawdown required 17–20 days (10.2 cm/day) and was maintained until 15 October. The lake was usually refilled by 15 February. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Macrophytes were reduced by 90% over the three year period. The weight of desirable-sized and fingerling-sized fish increased while a decrease occurred for the intermediate-sized fish. There was an improvement in fishing success. **REFERENCES:** Lantz et al. (1964).

LAKE NAME: Annabessacook

LOCATION: Kennebec Co., Maine, USA
SURFACE AREA: 5.7 km^2
MAXIMUM DEPTH: 17 m

PROBLEM: Nuisance blue-green algal blooms. Eutrophic conditions apparently induced by the influx of municipal and individual wastes. **RESTORATION OBJECTIVE:** To limit the algal growth by reducing the concentration of nitrogen and phosphorus. **RESTORATION METHODOLOGY:** Sewers are being installed to intercept most of the municipal and industrial wastes. These are pumped out of the basin for treatment and disposal. Better land use practices have been suggested for the near shore areas to deal with septic tank and lawn fertilizer problems. Aeration of the deepest portion of the lake was tried during the 1972 summer, but the results are not yet available. The cost for diversion channels and pumping stations is about $1,217,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Results are not yet available. Pre-treatment studies included estimation of a nutrient budget. Wastewaters contributed 93% (about 10,300 kg/yr) and 46% (about 7,800 kg/yr) of the inflowing phosphorus and nitrogen, respectively. **REFERENCES:** Hall (pers. comm.; reports are in preparation), Scott (pers. comm.), Scott (1971).

LAKE NAME: Apopka Lake

LOCATION: Lake and Orange Cos., Florida, USA
SURFACE AREA: 120 km^2
MAXIMUM DEPTH: 4 m

PROBLEM: Extremely eutrophic and heavily overpopulated with trashfish. Since the appearance of the first severe algal blooms in 1947, macrophytes have virtually disappeared and fish spawning and breeding grounds have become covered with organic sediments. Excessive nutrients enter the lake from surrounding muck farms, municipalities, and industries. **RESTORATION OBJECTIVE:** To reduce the nutrient input and the in-lake nutrient recycling by: (1) elimination of point nutrient sources, and (2) lake drawdown for sediment oxidation and consolidation. **RESTORATION METHODOLOGY:** A 2 m drawdown is planned to expose about 50% of the bottom. Assuming that only those bottom sediments exposed at a level of about 0.6 m above the lowered lake surface will consolidate, about 25% of the lake bottom will be affected. Both pumping and gravity draining will be used to lower the lake level; treatment of the discharged water will probably be necessary for the removal of algae, suspended solids, and nutrients. The nutrient influx will be eliminated by the use of a combination of holding ponds, advanced waste treatment, and spray irrigation of wastewaters. The estimated cost of the entire project is $2,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The probable effects of drawdown on lake water quality are now being evaluated in the laboratory. Preliminary results indicate that desiccation has little effect on inorganic nitrogen and phosphorus levels in the sediment. **REFERENCES:** Anderson (1971), Brezonik (pers. comm.), Florida Dept. of Pollution Control (1972), Fox (pers. comm.), Osborne (pers. comm.; several reports are available), Pride (pers. comm.), Schneider (pers. comm.), Schneider and Little (1971), Scott (pers. comm.; reports are available), Sheffield and Kuhrt (1970), Winn (pers. comm.).

LAKE NAME: Arbor Lake

LOCATION: Chicago, Illinois, USA
SURFACE AREA: 5 ha
MAXIMUM DEPTH: 5.2 m

PROBLEM: Periodic winterkills due to dissolved oxygen depletion. **RESTORATION OBJECTIVE:** To oxygenate the lake during the winter. **RESTORATION METHODOLOGY:** A commercial aeration system was installed in 1962, consisting of a shore-based electric compressor connected to 100 m of perforated tubing anchored on the lake bottom. Total cost for the system was about $620 USA, and operating costs were about $0.01/hr. The system was thermostatically controlled, operating only when the air temperature dropped below 2° C. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The system maintained a 200 m^2 area of the lake ice-free and eliminated winterkill. Open water attracted numerous migratory birds during the winter. **REFERENCES:** Farm Pond Harvest (1969).

LAKE NAME: Ardmore City Lake

LOCATION: Carter Co., Oklahoma, USA
SURFACE AREA: 74.5 ha
MAXIMUM DEPTH: 9.8 m

PROBLEM: Slow-growing, overcrowded populations of white and black crappies *(Pomoxis* spp.); poor sport fishing.

RESTORATION OBJECTIVE: To improve the sport fishery by killing 80% of the population thereby creating conditions conducive to greatly accelerated growth. **RESTORATION METHODOLOGY**: Population reduction was attempted in Sept., 1953. About 1160 kg of powdered rotenone was applied to approximately 80% of the lake's surface. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Large numbers of all species were killed. However, crappie reproduction was subsequently very high and although first year growth was 5.1 cm greater than before treatment, fishing success was poor during 1954 and 1955. Rapid population expansion for the crappies and other species quickly curtailed growth. **REFERENCES**: Jenkins (1955, 1956).

LAKE NAME: Arthur

LOCATION: Butler Co., Pennsylvania, USA

SURFACE AREA: 12.1 km^2

MAXIMUM DEPTH: 9.2 m

PROBLEM: Influx of silt and acids from nearby mining operations. **RESTORATION OBJECTIVE**: To reduce the silt and acid load. **RESTORATION METHODOLOGY**: The boney piles and other waste materials were moved and contoured. Vegetation was planted on all of the exposed soil areas. Concrete plugs were placed in the openings of 50 unused mines at a cost of $2,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Erosion was eliminated from several hundred hectares of spoil piles. The acid load was reduced by 75%. **REFERENCES**: Shellgren (pers. comm.).

LAKE NAME: Ascarate

LOCATION: El Paso, Texas, USA

SURFACE AREA: 18.3 ha

MAXIMUM DEPTH: 1.8 m

PROBLEM: Poor quality sport fishery; overabundant gizzard shad *(Dorosoma cepedianum)* and slow-growing panfish. **RESTORATION OBJECTIVE**: To reduce the problem fish populations, to introduce threadfin shad *(Dorosoma petenense)* as a forage species and as a competitor with gizzard shad, and to supplement the gamefish populations. **RESTORATION METHODOLOGY**: In December, 1970 a selective kill of the overabundant, problem species was attempted using powdered cube root (6.7% rotenone). The entire lake was treated at a concentration of 0.19 mg/l by spraying from a boat. The total expenditures were $1500 USA. Threadfin shad and gamefish were stocked in March, 1971. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Small gizzard shad died first; the average size increased as the treatment continued. There was almost no effect on the stunted panfish population. A few crappies *(Pomoxis* spp.) of all sizes were killed. Surface netting and trawling recovered 6.1 kg of dead shad/ha. **REFERENCES**: Morris (1971).

LAKE NAME: Ashurst

LOCATION: Arizona, USA

SURFACE AREA: 81 ha

MAXIMUM DEPTH: 5.5 m

PROBLEM: Overabundant macrophyte growth; summer maximum pH exceeding 10.0. **RESTORATION OBJECTIVE**: To reduce the light penetration by dye introduction. **RESTORATION METHODOLOGY**: Nigrosine dye, at a cost of $1.00 USA/130 kg (1945 price), was applied to the lake at a concentration of 11 kg/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The dye was applied during late spring, 1945. No effect was observed the first summer, but in 1946, no macrophytes reached the surface and growth appeared to be inhibited throughout the lake. Fifty per cent of the original dye strength was present after 12 months and 40% after 18 months. *Myriophyllum*, which dominated in this lake, did not mature in 1946. **REFERENCES**: Eicher (1947).

LAKE NAME: Lake Austin

LOCATION: Austin, Texas, USA

SURFACE AREA: --

MAXIMUM DEPTH: --

PROBLEM: Overabundant growth of milfoil *(Myriophyllum* sp.). **RESTORATION OBJECTIVE**: To enhance recreational usage by macrophyte reduction. **RESTORATION METHODOLOGY**: Three procedures were tested: (1) winter drawdown, (2) herbicides (2,4–D), and (3) winter drawdown with application of soil sterilants (2,4–D, borax, and CMU). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Winter drawdown combined with the application of soil sterilants gave the best results. Macrophyte control was possible for a two-year period, minimum. **REFERENCES**: Steel and Ewing (1954).

LAKE NAME: Babson Reservoir

LOCATION: Gloucester, Massachusetts, USA

SURFACE AREA: 14 ha

MAXIMUM DEPTH: 9.1 m (full pool)

PROBLEM: High color, iron, and manganese concentrations during the summer. Used as a water supply reservoir. **RESTORATION OBJECTIVE**: To improve the water quality in order to provide a more dependable water supply. **RESTORATION METHODOLOGY**: An aeration system was installed in 1960. Air was supplied with a positive displacement blower, rated at 220 l/sec at 0.5 kg/cm^2. A 12 m perforated pipe was installed 2.4 m below the water surface near the deepest point of the reservoir. Aeration began in September, 1960 and continued through the winter and into the summer of 1961. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After 20 days of operation, thermal and chemical stratification was eliminated. Dissolved oxygen concentrations were uniform from top to bottom. Using Rhodamine B as a tracer, it was determined that the aerator mixed the entire reservoir volume in about 24 hours. The aerator prevented the reservoir from completely freezing over and the water temperature averaged about 1°C during the winter. Algae increased due to aeration, resulting in a more desirable alkalinity; and color decreased. Preliminary data indicated that iron, manganese, and pH were not significantly affected by aeration. **REFERENCES**: Nickerson (1961).

LAKE NAME: Backbone Lake

LOCATION: Delaware Co., Iowa, USA

SURFACE AREA: 51 ha

MAXIMUM DEPTH: 3.7 m

PROBLEM: Overabundant carp population *(Cyprinus carpio)*. **RESTORATION OBJECTIVE**: To selectively control the carp population during spawning activities. **RESTORATION METHODOLOGY**: Antimycin (Fintrol–5) was applied to 1.6 ha of the lake (spawning areas) in June, 1967. The concentration was 50 μg/l of antimycin. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Only about 1000 kg of dead carp were recovered. Largemouth bass *(Micropterus salmoides)* were also killed in limited numbers. The number of carp killed was considered insufficient for population control; the lack of success in this attempt was due to heavy precipitation that occurred eight hours after treatment. **REFERENCES**: Helms (1967).

LAKE NAME: Barcroft
LOCATION: Fairfax Co., Virginia, USA
SURFACE AREA: 55 ha
MAXIMUM DEPTH: --

PROBLEM: Serious erosion and sedimentation problems due to urbanization of the drainage basin. Each 2.6 km^2 of suburban construction contributed approximately 23,000 metric tons of sediment to the lake. **RESTORATION OBJECTIVE**: To remove the sediment from the lake and protect it from further sediment influx. **RESTORATION METHODOLOGY**: The property owners association, in cooperation with other active citizen groups, raised funds to dredge the lake and to construct an improved drainage system. Erosion and sediment control measures were enacted by the county government. Approximately $300,000 USA was spent during 1960–70 to remove the sediments and to retard the sediment influx. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In 1970, about 4,000 m^3 of sediment were being dredged each year. Erosion control measures successfully controlled further sedimentation. **REFERENCES**: Powell et al. (1970).

LAKE NAME: Bass Lake
LOCATION: Starke Co., Indiana, USA
SURFACE AREA: 6.5 km^2
MAXIMUM DEPTH: 9.2 m

PROBLEM: Increased turbidity; lack of macrophytes; and deteriorating sport fishery. **RESTORATION OBJECTIVE**: To improve the conditions through the removal of trashfish species, primarily carp *(Cyprinus carpio)*. **RESTORATION METHODOLOGY**: Fish were removed by seining in 1935 and 1936. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The trashfish population was composed of carp, buffalo *(Ictiobus* spp.), quillback *(Carpiodes* spp.) and gar (*Lepisosteus* spp.) The catch in numbers per seine haul decreased for carp and quillback but increased for gar in 1936. The catch in numbers per seine haul increased for all gamefish species in 1936. During the two years 409,000 kg of carp, 17,300 kg of quillback, 5,450 kg of buffalo, and 454 kg of gar were removed. It was also noted that water clarity and macrophyte abundance both increased following the removal operations. **REFERENCES**: Ricker and Gottschalk (1940).

LAKE NAME: Bass Lake
LOCATION: Itasca Co., Minnesota, USA
SURFACE AREA: 78.2 ha
MAXIMUM DEPTH: --

PROBLEM: Slow-growing bluegill *(Lepomis macrochirus)* population. **RESTORATION OBJECTIVE**: To determine the value of removal as a means of improving the growth and average size of the remaining bluegills. **RESTORATION METHODOLOGY**: In 1956 1.5 kg/ha of panfish were removed by seining and trapnetting; and the lake was heavily stocked with adult and yearling northern pike *(Esox lucius)* (2.2 to 5.6 kg/ha). Subsequent sampling was conducted in 1958. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In 1956 the highest percentage of the catch was three-year-old bluegills; in 1958 it was five-year-olds. There was no apparent effect on the bluegill growth rate. **REFERENCES**: Scidmore (1960).

LAKE NAME: Bear Pond
LOCATION: Paul Smiths, New York, USA
SURFACE AREA: 1.9 ha
MAXIMUM DEPTH: 5.8 m

PROBLEM: Nearly complete salmonid fishkill during the winter. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen conditions and prevent winterkill. **RESTORATION METHODOLOGY**. The pond was aerated during the winters of 1961–62 and 1962–63 by using irrigation equipment and a 22 l/sec pump to spray oxygen-deficient water into the air. The water ran back into the lake through holes cut in the ice. Approximately 60 m of irrigation pipe was used, with nozzles at 6 m intervals. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Spraying increased the oxygen content of the water from 1.2 mg/l to 12.4 mg/l, and decreased the temperature by about 3°C. The oxygen levels again decreased, however, as the water mixed with oxygen-deficient lake water. Increasing the number of drain holes reduced turbulent mixing, and within two days the concentrations increased from 2.4 mg/l to 10.0 mg/l in the upper meter near the spray area and from 2.4 mg/l to 5.2 mg/l at a distance of 18 m. Dye introduced into the pumped water indicated that the oxygenated water spread horizontally in a thin layer under the ice, with little vertical mixing. Salmonids apparently detected the oxygen gradient and concentrated near the spray area. **REFERENCES**: Flick (1968).

LAKE NAME: Bear Camp Lake
LOCATION: Georgia, USA
SURFACE AREA: 26.3 ha
MAXIMUM DEPTH: --

PROBLEM: Poor fishing success. **RESTORATION OBJECTIVE**: To evaluate the effect of overwinter drawdown and fish removal upon the fish population. **RESTORATION METHODOLOGY**: During October–January, 1963 the pond was lowered about 50%. In 90 days 853.5 kg of golden shiners *(Notemigonus crysoleucas)* were removed by netting. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There was an improvement in the condition of all gamefish species. The golden shiner population was reduced greatly during 1963; high reproduction was noted but these were apparently preyed upon heavily. The black crappie *(Pomoxis nigromaculatus)* population benefited the most from this management program, although the largemouth bass *(Micropterus salmoides)* and bluegill *(Lepomis macrochirus)* populations also responded favorably. **REFERENCES**: Pierce et al. (1963).

LAKE NAME: Beaver Lake
LOCATION: Steele Co., Minnesota, USA
SURFACE AREA: 43.7 ha
MAXIMUM DEPTH: 9.2 m

PROBLEM: Overabundant carp *(Cyprinus carpio)* population. **RESTORATION OBJECTIVE**: To determine the effect of partial removal on the carp and gamefish populations. **RESTORATION METHODOLOGY**: Removal by seining began in the winter of 1955–56 and ended in 1956–57. The weight of carp removed varied from 2.0 to 44.9 kg/ha. The gamefish investigation began in the summer of 1955 and ended in 1957. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: It was not possible to correlate year-class strength with the removal effort due to the short period of study, but the dominant year-classes for bluegills *(Lepomis macrochirus)* and white and black crappies *(Pomoxis* spp.) originated prior to the removal operations. There was no indication of a consistent improvement in growth following removal. Harvesting did not affect the carp population structure. **REFERENCES**: Scidmore and Woods (1961).

LAKE NAME: Beaver Dam Lake
LOCATION: Dodge Co., Wisconsin, USA
SURFACE AREA: 27 km^2
MAXIMUM DEPTH: 2.2 m

PROBLEM: Low dissolved oxygen concentrations during the winter. **RESTORATION OBJECTIVE**: To improve the winter dissolved oxygen conditions and prevent winterkill. **RESTORATION METHODOLOGY**: An aeration system which consisted of 32 45 cm diameter, 0.9 m long "Helixors" was installed in the 11 km^2 southeast basin. The "Helixors" were connected via 6.7 km of weighted polyethylene air line to two shore-mounted rotary blowers capable of delivering 390 l/sec of air. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The system was installed in the winter of 1970–71. It maintained a 30–40 ha open area during the winter and dissolved oxygen was held at satisfactory levels. During the summer of 1971, however, the "Helixors" silted up, settled into the lake bottom, and became inoperable. Annual spring removal of the "Helixors" would be necessary to permit continued operation. **REFERENCES**: Wirth (1970).

LAKE NAME: Beckers Lake
LOCATION: Apache Co., Arizona, USA
SURFACE AREA: 43 ha
MAXIMUM DEPTH: 8.8 m

PROBLEM: Overabundant trashfish populations. **RESTORATION OBJECTIVE**: To study toxaphene as a possible toxin for fish population control. **RESTORATION METHODOLOGY**: The lake was treated with toxaphene in October, 1951. A concentration of 0.1 mg/l was achieved. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Fish began dying 30 hours after application. Distressed fish were observed for 1–1/2 to 2 weeks. Yellow perch *(Perca flavescens)* appeared to die first, then golden shiners *(Notemigonus crysoleucas)*, and lastly carp *(Cyprinus carpio)*. No trashfish species were caught in the lake during periodic sampling for the next two years. In spring, 1952 rainbow trout *(Salmo gairdnerii)* were stocked; they subsequently exhibited a good rate of growth. Water clarity (Secchi disk) increased from 0.3 to 2.1 m after treatment. **REFERENCES**: Hemphill (1954).

LAKE NAME: Bedford Reservoir
LOCATION: Pittsburgh, Pennsylvania, USA
SURFACE AREA: 4000 m^2
MAXIMUM DEPTH: 3 m

PROBLEM: Bottom accumulations or organic sludge, high concentrations of iron and manganese, and problem algal growths. During periods of high discharge from this pumped water storage reservoir, the bottom sediments were disturbed and turbidity also became a problem. **RESTORATION OBJECTIVE**: To determine if aeration/circulation would improve the water quality. **RESTORATION METHODOLOGY**: An aeration system was installed to supply air to 360 m of weighted perforated tubing on the reservoir bottom using an electrically powered compressor rated at 8.5 l/sec. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Continuous operation of the aeration system resulted in a dramatic decrease in turbidity. The water clarity increased from about 1.2 m to more than the depth of the reservoir. Bottom deposits were eliminated, and iron and manganese concentrations were reduced to nearly zero. Total hardness and pH were unaffected. Taste and odor complaints were eliminated. With the aeration system operating, the reservoir did not freeze during the winter. The success of the system induced the installation of aeration systems in four additional reservoirs. **REFERENCES**: Clair and Beck (1969).

LAKE NAME: Lake Beulah
LOCATION: near Lakeland, Florida, USA
SURFACE AREA: 7.3 ha
MAXIMUM DEPTH: 8.5 m

PROBLEM: Overabundant gizzard shad *(Dorosoma cepedianum)* population. **RESTORATION OBJECTIVE**: To determine if the gizzard shad population could be controlled selectively using a piscicide. **RESTORATION METHODOLOGY**: Four treatments with a 0.1 mg/l concentration or less of 5% emulsified rotenone were used. Application occurred by boat in March, 1955; March, 1956; July, 1956; and July, 1957. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The treatments had little effect on non-shad fish species. Threadfin shad *(Dorosoma petensis)* apparently were completely eliminated by the first treatment. The greatly reduced gizzard shad population reproduced and exhibited rapid growth. The estimated weight of gizzard shad killed ranged from 1462 kg/ha in the first treatment to 66 kg/ha in the last. **REFERENCES**: Huish (1957).

LAKE NAME: Beulah
LOCATION: East Troy, Wisconsin, USA
SURFACE AREA: 4.5 km^2
MAXIMUM DEPTH: --

PROBLEM: Heavy growths of rooted vegetation, in particular pondweed *(Potamogeton)*, coontail *(Ceratophyllum)*, milfoil *(Myriophyllum)*, and *Chara*. **RESTORATION OBJECTIVE**: To harvest the vegetation for nutrient removal and increased usability of the lake. **RESTORATION METHODOLOGY**: A mechanical harvester was used to remove the vegetation. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Since 1971 6.5×10^5 kg (wet weight) of vegetation were removed, containing 717 kg of nitrogen and 292 kg of phosphorus. Three years of removal reduced the in-lake phosphate concentration by 0.125 mg/l (80%) and the nitrate concentration by 0.05 mg/l (39%). **REFERENCES**: East Troy Sanitary District No. 1 (1971).

LAKE NAME: Big Lake
LOCATION: Arizona, USA
SURFACE AREA: 2.2 km^2
MAXIMUM DEPTH: 5.8 m

PROBLEM: Overabundant *Elodea* during the summer (covers over 80% of the lake's surface); winterkill every 2–3 yrs. **RESTORATION OBJECTIVE**: To prevent winterkill by improving the dissolved oxygen conditions and promoting an early spring ice-out. **RESTORATION METHODOLOGY**: An aeration system consisting of 730 m of perforated tubing was laid across the entire width of the lake on the bottom. Air was supplied with a 99 l/sec shore-mounted compressor. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Aeration began on 20 February, 1954, when the dissolved oxygen concentration was 2.1 mg/l. After 72 hrs. of continuous operation, a 270 m long channel averaging 6 m in width was open above the air line. After 12 days of operation, the channel nearly traversed the entire lake. Dissolved oxygen concentrations increased to

5.3 mg/l at a distance of 180 m from the channel, but continued to decline to less than 0.5 mg/l in other parts of the lake. Ice breakup on the lake took place about 30 days earlier than usual and the aerator was apparently successful in preventing winterkill. **REFERENCES**: Hemphill (1955).

LAKE NAME: Big Lake
LOCATION: Holt Co., Missouri, USA
SURFACE AREA: 2.5 km^2
MAXIMUM DEPTH: 1.2 m (before dredging)

PROBLEM: Severely restricted recreation due to excessive siltation. In its 150-year history, approximately 5.7 x 10^6m^3 of silt have been deposited in the lake by flood waters. **RESTORATION OBJECTIVE**: To remove the accumulated silt in order to deepen the lake and restore it for outdoor recreational activities, such as boating and fishing. **RESTORATION METHODOLOGY**: In 1966, a 20 cm hydraulic dredge began operating in the lake. Amortization of the cost of the dredging equipment over a 15-year period and costs of supporting equipment, fuel, and personnel gave a total annual expenditure of $26,700 USA. Annual production of the dredge was about 420,000 m^3, at a cost of $0.06/m^3. No expenditures were necessary for spoil disposal areas. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A series of channels representing 15 to 20% of the lake's surface area have been dredged to a depth of 2.4 m. Slumping of sediments along the channel borders has also resulted in increased depth in the undredged areas. A 15-year dredging program is anticipated, and a series of levees will be required to prevent the influx of flood waters in the future. **REFERENCES**: Michaelson (pers. comm.), Otke (pers. comm.), Russell and Axon, Inc. (1968).

LAKE NAME: Big Alum Pond
LOCATION: Massachusetts, USA
SURFACE AREA: 79 ha
MAXIMUM DEPTH: 13.7 m

PROBLEM: Overabundant panfish. **RESTORATION OBJECTIVE**: To reduce the population of panfish. **RESTORATION METHODOLOGY**: Emulsifiable rotenone (5%) was used to give an epilimnetic concentration of 0.5 mg/l. The littoral zone and 10 ha of open water (16.2 ha in total) were treated in July, 1955. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About one-third of the fish standing crop in the lake was eliminated; the majority of these fish were panfish. The population of cold water fish species that existed below the epilimnion was unaffected by treatment. **REFERENCES**: Tompkins and Mullan (1958).

LAKE NAME: Big Bear Lake
LOCATION: San Bernardino Co., California, USA
SURFACE AREA: 10.5 km^2
MAXIMUM DEPTH: --

PROBLEM: Overabundance of goldfish *(Carrassius auratus)*, providing competition for food and a source of parasitic infection for the other fish species. **RESTORATION OBJECTIVE**: To eradicate goldfish and the ectoparasitic copepod, *Lernaea carassii*. **RESTORATION METHODOLOGY**: The lake was partitioned into two sections and treated by airplane with toxaphene in September, 1960. Two previous treatments with rotenone had resulted in incomplete kills. The upper part of the lake was treated on the 7th (0.05 mg/l), 16th (0.05 mg/l), and 26th (0.10 mg/l). The lower part was treated on the 13th (0.03 mg/l) and the 28th (0.10 mg/l). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A few shore birds and waterfowl were killed by toxaphene treatment. The goldfish kill was incomplete and tissue analysis of survivors revealed toxaphene concentrations previously thought to be lethal. Bioassays indicated the lake detoxified after 10 months; fish were then restocked and the lake opened to fishing. **REFERENCES**: Johnson (1966).

LAKE NAME: Big Cedar Lake
LOCATION: Washington Co., Wisconsin, USA
SURFACE AREA: 4.1 km^2
MAXIMUM DEPTH: 32 m

PROBLEM: Excessive macrophytes; occasional algal blooms. **RESTORATION OBJECTIVE**: To retard premature eutrophication. To limit the influx of nutrients to the lake. **RESTORATION METHODOLOGY**: At the present time the macrophytes are harvested mechanically and the algae are controlled with algicides. A wastewater collection and diversion system is also under consideration. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Macrophyte harvesting sustains the use of all lake areas for recreational purposes. Algicide dosing is in disfavor because it treats symptoms and not ailments. **REFERENCES**: Genthe (pers. comm., reports are available).

LAKE NAME: Billington Sea
LOCATION: near Plymouth, Massachusetts, USA
SURFACE AREA: 1.1 km^2
MAXIMUM DEPTH: 3.4 m

PROBLEM: Poor quality sport fishery. **RESTORATION OBJECTIVE**: To improve the gamefish populations by selective removal of overabundant panfish and trashfish. **RESTORATION METHODOLOGY**: Thinning operations were carried out in 1952, 1954, and 1956 using fyke nets. Removal amounted to 16.8, 15.1, and 9.4 kg/ha for these respective years. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The primary species removed were bluegills *(Lepomis macrochirus)* and white suckers *(Catostomus commersonnii)*. The composition of the catch in the fyke nets suggested no change in their population levels 1952 through 1956. There was little change in the white perch *(Morone americana)* growth rate, but there was a decrease in that of the yellow perch *(Perca flavescens)*. Chain pickerel *(Esox niger)* growth remained constant 1954 to 1956. **REFERENCES**: Grice (1958).

LAKE NAME: Black Lake
LOCATION: Natchitoches Parish, Louisiana, USA
SURFACE AREA: 81 km^2
MAXIMUM DEPTH: 6.1 m

PROBLEM: Excessive macrophytes due to shallow, clear water. **RESTORATION OBJECTIVE**: To prevent macrophytes from infesting the entire lake. **RESTORATION METHODOLOGY**: Several methods are under consideration. Chemical control is not economically feasible ($86.50–370 USA/ha). Water fluctuation is now being evaluated and the use of the white amur *(Ctenopharyngodon idellus)* is a future possibility. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Drawdown was implemented during the 1972–73 winter and will be repeated the next two years. The effects on both vegetation and water quality are being studied. **REFERENCES**: Sanders (pers. comm.), Sanders (1971).

LAKE NAME: Lake Blackshear
LOCATION: Crisp Co., Georgia, USA
SURFACE AREA: 34.5 km^2
MAXIMUM DEPTH: (mean depth, 2.8 m)

PROBLEM: Overabundant population of gizzard shad *(Dorosoma cepedianum)*. **RESTORATION OBJECTIVE**: To selectively remove a major part of the shad population. **RESTORATION METHODOLOGY**: In September, 1958 the lake was treated with a concentration of 0.13 mg/l emulsifiable rotenone. The piscicide was applied by boat and airplane. The cost of treatment was $15,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Gizzard shad of all sizes were killed; gamefish comprised an estimated 5–10% of the kill. Treatment effectively reduced the shad population for four years. The largemouth bass *(Micropterus salmoides)* population and catch increased temporarily but again declined when the shad increased in abundance. The bass produced a strong year-class in 1959 and predation by these fish were thought to be responsible for the continuation of low shad populations for four years. After treatment there was a 30% increase in the number of fishermen for the next three years. **REFERENCES**: Wyatt and Zeller (1962), Zeller and Wyatt (1967).

LAKE NAME: Lake Blackshear
LOCATION: Crisp Co., Georgia, USA
SURFACE AREA: 34.5 km^2
MAXIMUM DEPTH: (mean depth, 2.8 m)

PROBLEM: Excessive growths of water hyacinths *(Eichornia crassipes)* in areas inaccessible for mechanical harvesting. **RESTORATION OBJECTIVE**: To reduce the water hyacinths with 2,4–D. **RESTORATION METHODOLOGY**: The emulsifiable concentrate was used (0.72 kg active acid/l), a total of 1506 l for the initial and follow-up spraying of 2.1 km^2. Applications were made at rates ranging from 2.24–6.7 kg/ha, at an average cost of $57.04 USA/ha (costs in other treatments had been $4.05–30.38/ha). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The applications were very effective on the water hyacinths that received a drenching spray. However, usually regrowth rapidly developed from seeds of previous seasons, especially when the water level was lowered gradually during late summer. The treatment adversely affected the growth of other macrophytes but was not sufficient to kill their root systems. No fishkills were reported from the spray treatments of 2,4–D or from the reduction of dissolved oxygen due to decay of the macrophytes. **REFERENCES**: Gangstad (1972).

LAKE NAME: Blue Lake
LOCATION: near Portland, Oregon, USA
SURFACE AREA: 26 ha
MAXIMUM DEPTH: 9 m

PROBLEM: Excessive macrophyte growth; occasional algal blooms; possible accumulation of arsenic used as herbicide. **RESTORATION OBJECTIVE**: To reduce the macrophytes and to find and use a control method other than arsenic. **RESTORATION METHODOLOGY**: The use of arsenical herbicides was discontinued; a macrophyte harvester was constructed for $12,000 USA. The harvested vegetation has been removed from the lake. Domestic sewage was diverted from the individual septic tank systems to treatment plants. Harvesting and diversion have been in operation since 1969. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Macrophytes were satisfactorily controlled by the underwater cutter-type harvester. No information is available concerning the possible effects of sewage diversion. **REFERENCES**: McHugh (pers. comm.), McHugh (1972).

LAKE NAME: Boddie Pond
LOCATION: Lauderdale Co., Alabama, USA
SURFACE AREA: 7,000 m^2
MAXIMUM DEPTH: 0.9 m

PROBLEM: Excessive siltation; too shallow. **RESTORATION OBJECTIVE**: To drain and deepen the pond. Prior to drainage the fish population was removed for evaluation. **RESTORATION METHODOLOGY**: Rotenone (derris root powder) was applied by surface spraying from a boat in August, 1939. Approximately 11.4 kg of 5% rotenone was used for the total volume of 3030 m^3. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The fish were in poor condition; the standing crop was 246 kg/ha. *Ictalurus* spp. comprised about 80% of the population (by weight). Prior to elimination of the fish population, the water was extremely turbid; clarity was 2.5–5.1 cm and macrophytes were lacking. After treatment clarity increased to over 0.9 m and a dense algal growth developed within a few days. **REFERENCES**: Tarzwell (1940).

LAKE NAME: Boltz Lake
LOCATION: Kentucky, USA
SURFACE AREA: 40 ha
MAXIMUM DEPTH: 19 m

PROBLEM: Hypolimnetic water quality deterioration during the summer. Dissolved oxygen depletions result in the reduction and solution of iron and manganese, the formation of hydrogen sulfide, the production of excess carbon dioxide, and the cessation of aerobic decomposition of organic materials. **RESTORATION OBJECTIVE**: To assess the effects of destratification on water quality and to determine the relative efficiencies of different aeration/circulation techniques. **RESTORATION METHODOLOGY**: Artificial destratification occurred during August and September, 1965 using a 30 cm mixed flow pump suspended over the deepest part of the lake. The pump was mounted on an anchored raft and powered by a gasoline engine. The suction line extended to within 0.3 to 0.6 m of the lake bottom and the discharge line terminated at the lake's surface. During the spring and summer of 1966, the lake was destratified using compressed air released from 16 ceramic diffuser stones placed in the deepest part of the reservoir. A 91 m long air line connected the diffusers to a shore mounted electrically powered air compressor that delivered 52 l/sec of air at a pressure of 2.1 to 2.8 kg/cm^2. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Thermal stratification was largely but not completely eliminated during the five week pumping period in 1965. Aeration was more effective in breaking down thermal stratification during 1966. Noticeable improvements in lake water quality occurred during both test periods. Dissolved oxygen increased in the hypolimnion and sulfide and manganese were almost totally eliminated. Surface temperatures declined slightly, whereas the temperature of the bottom waters increased by about 10°C. Mixing during 1966 resulted in a reduction in the total standing crop of phytoplankton during each aeration period, although when mixing stopped, the phytoplankton counts rose again. Destratification for quality control would have been more effective if begun in the spring and continued through the summer. **REFERENCES**: Symons et al. (1966, 1967a and b, 1970).

LAKE NAME: Bonito Lake
LOCATION: near Capitan, New Mexico, USA
SURFACE AREA: 18.2 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of undesirable fish species. **RESTORATION OBJECTIVE:** To eradicate the existing fish population and restock. **RESTORATION METHODOLOGY:** In March, 1961–when the reservoir was only 7.7 ha in size–7270 kg of powdered cube root (5% rotenone) was applied at 2.0 mg/l. The piscicide was mixed into a paste, placed in burlap bags, and towed behind a boat. The affected fish were removed from the lake. The cost for rotenone, salaries, per diem, and outboard motor gas and oil was $120 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** An estimated 4540 kg of fish were eliminated with 81% being undesirable species. One problem species, goldfish *(Carassius auratus)*, survived the treatment; other species were not found. **REFERENCES:** Little (1961).

LAKE NAME: Booth (Standard) Lake
LOCATION: Charlevoix and Otsego Cos., Michigan, USA
SURFACE AREA: 13.2 ha
MAXIMUM DEPTH: 9.5 m

PROBLEM: Slow-growing fish population. **RESTORATION OBJECTIVE:** To increase the rate of growth by decreasing the population size. **RESTORATION METHODOLOGY:** About 6.5 ha were cordoned off and treated with rotenone. After detoxification the barrier was removed. Treatment occurred in September, 1937. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The treated area contained 24.5 kg/ha of fish, only 6.2 legal-sized gamefish/ha. An increased growth rate of rock bass *(Ambloplites rupestris)*, too great to be accounted for by any normal growth fluctuation, occurred in fish of all ages. This increased rate of growth was maintained for at least four years. Growth in weight also increased sharply following treatment and the mean coefficient of condition was improved greatly. **REFERENCES:** Beckman (1940, 1946).

LAKE NAME: Boston Lot Reservoir
LOCATION: Grafton Co., New Hampshire, USA
SURFACE AREA: 18.6 ha
MAXIMUM DEPTH: ---

PROBLEM: Nuisance blooms of blue-green algae (predominantly *Anabaena)* causing taste and odors in auxiliary municipal water supply. **RESTORATION OBJECTIVE:** Control of nuisance algal growth by copper sulfate treatment. **RESTORATION METHODOLOGY:** 227 kg of copper sulfate was applied in 1961 by the "bag drag" method. In 1963, applications of 45.4 and 90.8 kg were made at different times during the summer. The chemical costs for the 1963 treatments were $41 USA ($2.20/ha). The algicide was applied evenly to the 3.1 m depth. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** A severe fishkill resulted from the 1961 treatment because of a temporarily reduced volume of water in the pond. The 45.4 kg applied in 1963 had little effect on the algae. The subsequent treatment controlled the algae and killed no fish. There have been no blooms or taste and odor problems since 1963. **REFERENCES:** Frost (pers. comm.).

LAKE NAME: Brainard Lake
LOCATION: Cranbury, New Jersey, USA
SURFACE AREA: 5 ha
MAXIMUM DEPTH: 1.8 m

PROBLEM: Accumulation of silt; reduced water depth; extensive macrophyte growths; and reduced recreational opportunities. **RESTORATION OBJECTIVE:** To deepen the lake in order to enhance its recreational and aesthetic potential. **RESTORATION METHODOLOGY:** The lake is being deepened to a maximum depth of 2.7 m with a hydraulic dredge at a cost of about $1.30 USA/m^3 of sediment. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Dredging began in early 1973. Results are not yet available. **REFERENCES:** Munch (pers. comm.).

LAKE NAME: Browns Lake
LOCATION: Montana, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Shallow, productive lake with a history of periodic winterkills. **RESTORATION OBJECTIVE:** To prevent winterkill by improving the dissolved oxygen regime. **RESTORATION METHODOLOGY:** Several attempts were made to aerate the lake during the winters of 1961–65. An aeration system was operated during the winter of 1961–62 from November to March. It consisted of three small shore-mounted air compressors, each connected to an 1100 m long, perforated air line laid on the bottom. Holes were punched in the line at 3 m intervals with a sewing needle. This system operated three days during March, 1963 and again in late winter, 1964 and 1965. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** During severe cold spells in 1961–62 only a few 1–2 m diameter holes were kept ice-free. A severe fishkill was noted shortly after ice-out. During the winter of 1962–63, the single-compressor system opened up a channel over the entire length of the air line but did not increase the dissolved oxygen concentration of the water. During the winter of 1964–65, a slight increase in dissolved oxygen concentrations was observed during aeration, but the melting of the snow cover on the lake may have been partially responsible for the increase. The value of the aeration system in preventing winterkill was unproven. **REFERENCES:** Domrose (1963), Seaburg (1966).

LAKE NAME: Buck Lake
LOCATION: Itasca Co., Minnesota, USA
SURFACE AREA: 1.9 km^2
MAXIMUM DEPTH: ---

PROBLEM: Slow-growing panfish population. **RESTORATION OBJECTIVE:** To determine the value of increased cropping as a means of improving the growth and average size of the residual panfish. **RESTORATION METHODOLOGY:** In 1956 9 kg/ha of panfish were removed by seining and trapnetting; and the lake was heavily stocked with adult and yearling northern pike, *Esox lucius* (2.2 to 5.6 kg/ha). Subsequent sampling was conducted in 1958. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The bluegill *(Lepomis macrochirus)* catch was composed primarily of four-year-olds in 1956 and three-year-olds in 1958. There did not appear to be any change in the growth rate. **REFERENCES:** Scidmore (1960).

LAKE NAME: Buffalo
LOCATION: Texas, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundant carp *(Cyprinus carpio)* population. **RESTORATION OBJECTIVE:** To reduce the population by treating the spawning areas with a piscicide during peak activity. **RESTORATION METHODOLOGY**: Fintrol-5 was added to an inflowing creek and around part of the shoreline. Application was made by seed spreaders and by hand in 1967. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: An estimated 100,000 carp were killed; only three dead gamefish were found. However, dilution of the toxicant occurred within hours in the creek and along the shore (due to high winds). Pre- and post-treatment gill net surveys indicated no significant reduction in the population. Better results should occur in future testing if the spawning population is prohibited from leaving the area of concentration by some artificial barrier. **REFERENCES**: Crabtree (1967).

LAKE NAME: Bugh's Lake
LOCATION: Waushara Co., Wisconsin, USA
SURFACE AREA: 10.2 ha
MAXIMUM DEPTH: 5.5 m

PROBLEM: Overabundant population of small panfish. **RESTORATION OBJECTIVE**: To eliminate part of the panfish population in order to stimulate the rate of growth of the remaining fish. **RESTORATION METHODOLOGY**: Toxaphene (Coopertox No. 6) was applied to the epilimnion in May, 1962 at an average concentration of 5μg/l. Limnological studies were conducted before and after application; part of the population of fish above 7.6 cm in length were marked prior to treatment. Dead fish were examined after treatment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 32% of the marked bluegills *(Lepomis macrochirus)* were recovered; the population size was estimated at 408 kg/ha before treatment for bluegills over 7.6 cm in length. One year later no bluegills between 7.4 and 14 cm in length were found in the lake, indicating heavy mortality of small bluegills in 1962; the length-weight relationship also improved after treatment. **REFERENCES**: Primising and Hacker (1964b).

LAKE NAME: Bussey Lake
LOCATION: near Bastrap, Louisiana, USA
SURFACE AREA: 8.9 km^2
MAXIMUM DEPTH: 9.2 m

PROBLEM: Excessive macrophyte growths, undesirable fish population characteristics, and deteriorating sport fishery. **RESTORATION OBJECTIVE**: To determine the effect of water level fluctuations (drawdown) on the limnological conditions. **RESTORATION METHODOLOGY**: Drawdown occurred in 1962 and 1965. The water level was lowered about 2.5 m at a rate near 7.6 cm/day. Drawdown began in late October and refill, in March–February. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After the first drawdown, the macrophytes were reduced by over 95%. The rate of fish catch continued to decrease but the weight harvested increased by over 100%. After the second drawdown there appeared to be an increase in the predatory gamefish population. Drawdown temporarily reduced the number of anglers but there was not a significant effect on the quality of the fishery. **REFERENCES**: Davis and Hughes (1964, 1968), Lantz et al. (1964).

LAKE NAME: Butterfly
LOCATION: eastern Tennessee, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Excessive eutrophication due to the influx of organic wastes from septic tanks. **RESTORATION OBJECTIVE**: To compare lake productivity before and after diversion of wastes. To quantify the changes. **RESTORATION METHODOLOGY**: A sewer system was being constructed in the residential area surrounding the lake. The diversion of wastes from septic tank treatment was anticipated by the end of September, 1968. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Weekly diurnal studies of oxygen and community metabolism were made to estimate primary productivity; 11 physico-chemical parameters were also measured weekly. Plankton and benthos sampling were, in addition, taken periodically. The study was to be continued after diversion. **REFERENCES**: Bunting (1968).

LAKE NAME: Cachuma Lake
LOCATION: Santa Barbara Co., California, USA
SURFACE AREA: 12.5 km^2
MAXIMUM DEPTH: 61 m

PROBLEM: Hypolimnetic dissolved oxygen depletion; undesirable tastes and odors in water withdrawn for municipal supplies. Dense populations of algae. **RESTORATION OBJECTIVE**: To increase the dissolved oxygen concentration of the bottom waters and prevent the development of taste and odor problems. To reduce the algal population. **RESTORATION METHODOLOGY**: The first unit of a destratification system was installed in March, 1968 and consisted of a 280 l/sec compressor releasing air through a single 7.5 cm- diameter orifice located about 3 m off the bottom in 40 m of water. This unit was operated intermittently until May and then continuously until October, 1968. A second unit was installed in May. A 100 l/sec compressor and a smaller 75 l/sec standby compressor were connected to seven shop-built diffusers located along an 18-m length of pipe placed in 30 m of water. This unit was also operated continuously until October. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Operation of both aeration systems failed to prevent thermal stratification but delayed its onset until July, about two months later than usual. The thermocline was about 10–15 cm deeper than normal. The surface temperatures were about 2–3°C lower, and the bottom temperatures, 2–3°C higher, than during three control years, but no significant reductions in evaporation losses were noted. Despite aeration, the anaerobic zone in the hypolimnion became well-established at about the same time as in other years and the disagreeable taste and odors were not eliminated. Phytoplankton populations were unaffected by aeration. It was concluded that the destratification equipment was undersized for the size of the lake and that effective destratification may be uneconomical. **REFERENCES**: Busby (1973).

LAKE NAME: Caddo Lake
LOCATION: Texas and Louisiana, USA
SURFACE AREA: 142 km^2
MAXIMUM DEPTH: (mean depth, 0.9 to 2.4 m)

PROBLEM: Excessive macrophyte growths, primarily waterweed *(Elodea canadensis)* and milfoil *(Myriophyllum exalbescens)*. **RESTORATION OBJECTIVE**: To control the macrophytes for increased recreational use of the lake and to develop the economical uses of the macrophytes. **RESTORATION METHODOLOGY**: The macrophytes were harvested three times during the growing season using a Grinwald Thomas harvester. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The rate of macrophyte regrowth suggested that harvesting could have been done five to six times during the season. The harvested material appeared to be of most value when used as a supplemental poultry feed. Yields of about 2200 to 6300 kg (dry weight)/ha/yr were obtained with protein ranging from 18 to 21%; fiber, from 11 to 16%; and xanthophyll, from 0.08 to 0.12%. **REFERENCES**: Bailey (1965), Lange (1965).

LAKE NAME: Calhoun
LOCATION: Minneapolis, Minnesota, USA
SURFACE AREA: 1.8 km^2
MAXIMUM DEPTH: 27.4 m

PROBLEM: High populations of blue-green algae. **RESTORATION OBJECTIVE**: To shift the algal dominance from blue-green to greens. **RESTORATION METHODOLOGY**: An aeration (destratification) system was installed; compressed air was released at the 23 m depth starting August, 1972. Operational difficulties were encountered during the experiment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Lundquist (pers. comm.; a report is in preparation).

LAKE NAME: Canadarago
LOCATION: Otsego Co., New York, USA
SURFACE AREA: 7.7 km^2
MAXIMUM DEPTH: 12.8 m

PROBLEM: Blue-green algal blooms and summer oxygen depletion in the hypolimnion. Eutrophic conditions caused by excessive phosphorus loading from domestic sewage and land runoff. **RESTORATION OBJECTIVE**: To reduce the planktonic algal growth and improve the dissolved oxygen conditions by reducing the phosphorus concentration. To develop an effective control program that can be applied statewide. **RESTORATION METHODOLOGY**: Phosphorus will be removed from the domestic sewage. Control measures will be directed at the septic tank systems around lake. Land use plans will be instituted to reduce the agricultural runoff. Plans are now being implemented. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The total investigation began in 1968 and involves studies of water chemistry, runoff, phytoplankton, macrophytes, zooplankton, benthos, fish, runoff control, and community decision making. A nutrient budget has also been constructed. Studies will continue through the post-treatment phase of this project. **REFERENCES**: Fuhs (pers. comm.; reports are available), Green (pers. comm.), Hetling (pers. comm.).

LAKE NAME: Capitol
LOCATION: Olympia, Washington, USA
SURFACE AREA: 1.2 km^2
MAXIMUM DEPTH: 6.1 m

PROBLEM: Nuisance growth of macrophytes in the summer due to nutrient influx and shallow water. About 39,500 m^3 of sediment are carried into the lake each year. The lake is used for rearing salmonids. **RESTORATION OBJECTIVE**: To control the macrophytes and increase the lake depth. **RESTORATION METHODOLOGY**: Herbicide application occurred in 1968. The water level was lowered in 1971; the bottom was frozen and the macrophytes exposed to the atmosphere. In 1972 the lake was filled with salt water for a few days. Dredging may be undertaken in the future. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Salt-water treatment showed promise as an inexpensive control for macrophytes. Detrimental effects on salmonid production or recreational activities will not result if the treatment is applied at the proper time of year. **REFERENCES**: Finn, Jr. (pers. comm.), Finn, Jr. (1972).

LAKE NAME: Carbody Reservoir
LOCATION: near Greeley, Colorado, USA
SURFACE AREA: 9.2 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of undesirable fish species, primarily carp *(Cyprinus carpio)*. **RESTORATION OBJECTIVE**: To selectively reduce the carp population. **RESTORATION METHODOLOGY**: Calcium carbide was mixed with rendered beef tallow and made into pellets. About 10,000 to 12,000 pellets were broadcast over a 6700 m^2 area in 0.9 to 1.2 m of water during carp spawning activities. The shoreline area was periodically checked for dead fish and nets were set in the treated area. The cost of materials was $7.20 USA; the study was conducted in the mid 1950's. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: One of 15 crappies (*Pomoxis* spp.) and none of the carp caught in the nets three days after treatment contained the carbide mixture. Several species of fish were found dead along the shoreline on the 3rd day but carbide was positively identified in one dead crappie only. Nine and four dead carp were found along the shoreline seven and 10 days, respectively, after treatment but the advanced stage of decomposition precluded carbide analyses. **REFERENCES**: Huston (1956).

LAKE NAME: Carlinville
LOCATION: Carlinville, Illinois, USA
SURFACE AREA: 68 ha
MAXIMUM DEPTH: ---

PROBLEM: Accumulation of sediment. The storage capacity has decreased by about 20,000 m^3/yr. **RESTORATION OBJECTIVE**: To increase the water storage capacity to meet the municipal demand. **RESTORATION METHODOLOGY**: A 20 cm hydraulic cutterhead dredge began removing sediment in 1968. The total cost of the dredge was about $89,000 USA, and the total expenses for its operation during the first year were about $9,400. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 83,000 m^3 of sediment were removed during the period, 1968–71. During this time the cost of dredging more than doubled due to labor disputes and the project was abandoned. The spoils disposal area was converted to agricultural use and produced a bumper crop of wheat without fertilizer the first year. **REFERENCES**: Roberts (pers. comm.), Roberts (1969).

LAKE NAME: Carlton
LOCATION: Orange and Lake Cos., Florida, USA
SURFACE AREA: 1.6 km^2
MAXIMUM DEPTH: 5.2 m

PROBLEM: Declining sport fishery; absence of macrophytes; nuisance algal blooms. Soft muck deposits covered 80% of the lake bottom and supported only a small benthic population. **RESTORATION OBJECTIVE**: To investigate and evaluate the effects of habitat manipulation on the fishery. To develop procedures that could also be applied elsewhere. **RESTORATION METHODOLOGY**: A hydraulic cutterhead dredge was employed to redistribute the bottom materials. Sand from mid-lake areas was deposited near shore in water depths of 3 to 4 m. The sand was placed over the existing muck. Costs for dredging operations were about $0.37 USA/m^3, exclusive of engineering, administrative, and legal costs. An estimated 49,000 m^3 of sand was dredged and additional expenses increased the total dredging cost to $26,941.24, or about $0.55/m^3. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 3.9 ha of muck bottom was successfully converted to sand; an additional 1.9 ha of converted bottom were unsatisfactory due to subsequent muck accumulations as suspended sediments settled out of the water column. Attempts at washing the muck off of the sand met with only limited success. The turbidity created by the dredging operation resulted in decreased algal productivity, and a concurrent decline in macrophytes was noted. Studies are currently underway to evaluate the effect of habitat manipulation on benthic populations and fish production. **REFERENCES**: Wilbur (pers. comm.), Wilbur and May (1970), Wilbur and Langford (1972 a and b).

LAKE NAME: Carlton Pond
LOCATION: Augusta, Maine, USA
SURFACE AREA: 89 ha
MAXIMUM DEPTH: 3.1 m

PROBLEM: Taste and odor problems; used as a municipal water supply. **RESTORATION OBJECTIVE**: To alleviate the algal-caused taste and odor problems. **RESTORATION METHODOLOGY**: Copper sulfate was applied by boat at a rate necessary to achieve 0.35 mg/l. The entire lake was treated each time. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The nuisance algae, primarily *Synura* and *Asterionella* were usually eliminated with only one treatment. **REFERENCES**: Anthony (1969).

LAKE NAME: Carnegie Lake
LOCATION: Princeton, New Jersey, USA
SURFACE AREA: 1.1 km^2
MAXIMUM DEPTH: 3 m

PROBLEM: Sediment accumulation at the rate of 10^7 kg/yr. Turbid; shallow; and excessive macrophytes. **RESTORATION OBJECTIVE**: To improve the conditions by sediment removal. To restore the recreational value of the lake. To limit the sediment influx. **RESTORATION METHODOLOGY**: During the winter of 1971–1972, dredging operations began with a 40 cm hydraulic cutterhead dredge. By March, 1973, approximately 760,000 m^3 of silt had been removed from the lake. Spoils were discharged to a diked-off, 20 ha disposal area. Total cost of the project was $1,000,000 USA (about $1.30/m^3). In order to prevent future sedimentation, several small reservoirs were constructed upstream. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The dredging was considered a complete success; the entire lake was deepened to a minimum depth of 1.8 m except for a 10 m wide strip along the shoreline which was left undisturbed. The effect of the dredging on lake ecology is being studied, but there were no immediate adverse effects noted. Dredging did create increased turbidity in the lake, and in the river downstream from the dam, but it was reportedly no more severe than what was normally experienced during periods of high runoff. **REFERENCES**: Bischoff (pers. comm.).

LAKE NAME: Carpenter Lake
LOCATION: near Owensboro, Kentucky, USA
SURFACE AREA: 28 ha
MAXIMUM DEPTH: 3.4 m

PROBLEM: Overabundant gizzard shad *(Dorosoma cepedianum)* population. **RESTORATION OBJECTIVE**: To improve the fish population and sport fishery by selectively removing most of the gizzard shad. **RESTORATION METHODOLOGY**: The lake was treated in October, 1954 with a low concentration (0.10 mg/l) of rotenone. Powdered rotenone was applied to the lake with an outboard motor operated pump. The dead fish were removed from the lake by a four man crew during the next week. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment resulted in the removal of 320 kg of shad/ha with a loss of less than 1.1 kg of other species/ha. **REFERENCES**: Bowers (1955).

LAKE NAME: Casitas Lake
LOCATION: Ventura, California, USA
SURFACE AREA: 11 km^2
MAXIMUM DEPTH: 82 m (full pool)

PROBLEM: High surface water temperatures and taste and odor problems in the bottom waters. Used for water supply. Algal control required an expenditure of about $20,000 USA/yr. **RESTORATION OBJECTIVE**: To maintain good water quality throughout the year by aeration. Only partial destratification was desirable, since low dissolved oxygen levels and water temperatures were necessary for certain industrial water users. **RESTORATION METHODOLOGY**: An aeration system was installed consisting of six perforated pipes suspended from a floating raft and connected to two on-shore electrically powered air compressors each rated at 149 l/sec. These replaced a single diesel compressor which was used during 1968 and 1969. The diffusers were placed about 21 m above the bottom. Capital cost for the system was about $42,400 USA; operation and maintenance costs were projected at $12,000 for about nine months of operation each year. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Surface water temperatures are maintained 1–2°C below pre-treatment levels and dissolved oxygen is present to the depth of the diffuser system. The fish (salmonids) have shown remarkable growth and fishing has improved. There have been significant cost savings at the water treatment facilities due to a reduction in chlorine demand and in iron and manganese concentrations. Only minor copper sulfate treatments have been required since operation of the system. **REFERENCES**: Barnett (1971), Howard (1972), Tognazzini and Barnett (pers. comm.; reports are available).

LAKE NAME: Lake Catherine
LOCATION: near Hot Springs, Arkansas, USA
SURFACE AREA: 12.1 km^2
MAXIMUM DEPTH: ---

PROBLEM: Poor fishing success; overabundant, undesirable fish species. **RESTORATION OBJECTIVE**: To selectively remove the gizzard shad *(Dorosoma cepedianum)* and drum *(Aplodinotus grunniens)*. **RESTORATION METHODOLOGY**: Pro-Noxfish was applied in October, 1958 during a drawdown period. Pro-Noxfish is a 2.5% rotenone preparation. The cost of the chemical was $5000 USA. The lake was divided into seven areas. Pro-Noxfish was used to give concentrations of 0.15 to 0.30 mg/l. A small amount of derris powder (5.7% rotenone) was also used. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Less than 1% of the kill consisted of gamefish. Subjective estimates placed the mortality (by weight) at 99% of the gizzard shad, 95% of the drum, and 5% of the gamefish populations. The lowered water level (1.2 m) realized a savings of $4400 USA in the chemical costs. Several gamefish species will be stocked before re-expansion of the trashfish population. **REFERENCES**: Mathis and Hulsey (1959).

LAKE NAME: Lake Catherine
LOCATION: Malvern, Arkansas, USA
SURFACE AREA: 12.1 km^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of macrophytes, primarily *Ceratophyllum demersum* and *Elodea* sp. **RESTORATION OBJECTIVE**: To control the macrophytes thereby enhancing water usage for recreation and power generation. **RESTORATION METHODOLOGY**: About 123 carp *(Ctenopharyngodon idella)*/ha were stocked annually for three years. The carp were roughly 20 cm in length; a total of 10,000 kg were introduced over the three year period. During this time the lake was also lowered 0.9 m each winter; subsequently 2.1 drawdowns were used annually (one exception, 1.5 m). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophyte problems–esp. *C. demersum* and *Elodea*–were almost completely eliminated after three years. **REFERENCES**: Mathis (1965).

LAKE NAME: Cayuga Lake
LOCATION: Tompkins, Cayuga, and Seneca Cos., New York, USA
SURFACE AREA: 172.1 km^2
MAXIMUM DEPTH: 132.6 m

PROBLEM: Mesotrophic lake with occasional nuisance blooms of phytoplankton during the summer. Also, nuisance growths of submerged macrophytes in part of the lake. **RESTORATION OBJECTIVE**: To determine the effects of a reduction in phosphorus input. **RESTORATION METHODOLOGY**: In June, 1973 the usage of phosphate detergents will be banned within the state of New York. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Several limnological parameters are under study. The lake is known to be phosphorus limited. **REFERENCES**: Child and Oglesby (1970), Child et al. (1971), Oglesby (pers. comm.), Oglesby and Allee (eds.) (1969).

LAKE NAME: Chabot Lake
LOCATION: Alameda Co., California, USA
SURFACE AREA: 1.3 km^2
MAXIMUM DEPTH: 18 m

PROBLEM: Dissolved oxygen depletion at the bottom during the summer; nuisance algal blooms. Used for recreation and water supply. **RESTORATION OBJECTIVE**: To increase the dissolved oxygen levels and control algal blooms. **RESTORATION METHODOLOGY**: Four "Helixors" were installed and copper sulfate was used at the application rate of 0.1 mg/l in the upper 3 m of water. The cost of the aeration system was about $6,000 USA, and copper sulfate treatment cost about $380/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Aeration has been somewhat effective in raising dissolved oxygen levels, but complete destratification has not been achieved. Copper sulfate effectively controls algal blooms. **REFERENCES**: Knutson (pers. comm.).

LAKE NAME: Chautauqua Lake
LOCATION: Jamestown, New York, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of submerged macrophytes, primarily milfoil *(Myriophyllum)* and waterweed *(Elodea canadensis)*. **RESTORATION OBJECTIVE**: To alleviate the nuisance conditions. **RESTORATION METHODOLOGY**: Two harvesters and several transport barges were used at a cost of approx. $123–173 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Macrophyte-free areas were maintained successfully. Recreational potential was enhanced greatly. The stalks of perennial plants, however, became quite rugged after cutting and were a nuisance in the swimming areas. **REFERENCES**: Livermore and Wunderlich (1969).

LAKE NAME: Chickahominy Reservoir
LOCATION: New Kent Co., Virginia, USA
SURFACE AREA: 4.5 km^2
MAXIMUM DEPTH: 4 m

PROBLEM: Profuse growths of *Egeria densa* (Planch) and *Elodea*. Accelerated eutrophication due to readily available nutrients. **RESTORATION OBJECTIVE**: To reduce and/or eliminate the macrophytes thereby improving storage capacity and recreational potential of the reservoir. **RESTORATION METHODOLOGY**: Slightly over 81 ha of the reservoir were treated during the three day period beginning 31 July, 1967 with 568.5 l of potassium endothall and 625.5 l of diquat using an airboat. The application rate was about 2.2 ha/hr. The costs in 1967 were $8.60 USA/l for diquat and $4.20/l for potassium endothall. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Fishing lanes were cleared 11 days after treatment. *Egeria* was cleared from the entire reservoir by the 34th day but some survival occurred, resulting in reinfestation. *Elodea* was reduced but not eliminated. Phytoplankton densities increased and initially restricted *Elodea* growth through limitation of light. Another treatment is planned for the spring of 1973. **REFERENCES**: Boone (pers. comm.), Corning and Prosser (1969), U.S. Army Corps of Engineers, Norfolk District and Virginia Commission of Game and Inland Fisheries (1972).

LAKE NAME: Lake Chicot
LOCATION: Lake Village, Arkansas, USA
SURFACE AREA: 19.4 km^2
MAXIMUM DEPTH: 9.2 m

PROBLEM: Turbid water; sediment infilling; and inflow of agricultural pesticides. **RESTORATION OBJECTIVE**: To restore the non-turbid condition of the lake and to improve water quality and fish and wildlife production. **RESTORATION METHODOLOGY**: Diversion canals, water control dams and structures, and a new pumping plant will be constructed to divert turbid flows now entering the lake from a large agricultural drainage basin. The problem arises primarily from the high, turbid flows in spring; the inflows will be diverted whenever a certain stage level is reached. The authorized project is in the detailed design stage but construction has not been initiated and is contingent on funding. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Some in-lake limnological measurements and sediment profiles of the lake bottom are available. Data collection will continue after treatment. **REFERENCES**: Bayley (pers. comm.).

LAKE NAME: Chicot Lake
LOCATION: Ville Platte, Louisiana, USA
SURFACE AREA: 7.3 km^2
MAXIMUM DEPTH: 4.9 m

PROBLEM: Excessive growth of submerged macrophytes; interference with boating access and fish balance. Accumulation of organic matter in the lake basin. **RESTORATION OBJECTIVE**: To provide an economic and ecologically safe means of reducing the spread of submerged macrophytes. To prevent further accumulation of organic matter. **RESTORATION METHODOLOGY**: The lake volume was reduced 70% by lowering the water level 1.8 m during the fall and winter months. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results of the study are presently being evaluated. This management technique has been used successfully in other lakes where: (1) morphology provides a deep channel to support fish life during the lowered stage, (2) all shallow areas supporting problem macrophytes are exposed to drying, and (3) the drainage basin is adequate to provide rapid refilling of the lake prior to early spring spawning of the fish species. Two to three consecutive years of drawdown are usually required for good results, thus necessitating good public support of the program. **REFERENCES**: Lantz (pers. comm.).

LAKE NAME: Clear Lake
LOCATION: Lake Co., California, USA
SURFACE AREA: 170 km^2
MAXIMUM DEPTH: 20 m

PROBLEM: Naturally eutrophic. Nuisance scums of blue-green algae, primarily *Aphanizomenon flos-aquae, Microcystis aeruginosa,* and *Anabaena solitaria.* **RESTORATION OBJECTIVE**: To control the growth of blue-green algae. **RESTORATION METHODOLOGY**: Several techniques have been tried or are under consideration. An oil skimmer was used to collect the surface scum which was then pumped through a microstrainer for removal of the algae. Also, about 3000 *Menidia audens* (Mississippi silversides) were stocked in October, 1967. These young-of-the-year were 50–70 mm in size and were introduced as a biological control for the midge and algal populations. Other techniques under study include: (1) aeration (not destratification because the lake is only transiently stratified), (2) local chemical control (copper sulfate and cutrine), (3) diversion of water into the lake, and (4) construction of an upstream reservoir to trap and retain the incoming sediments. A pilot test of aeration and mixing is scheduled for one small arm of the lake in 1973, although partial testing began in 1972. Three electrically-driven compressors will be used, together capable of delivering 470 l/sec of air to a diffuser system located in the deepest part of the arm. Total cost of the installation is estimated at about $50,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The results of algal harvesting showed the system to be feasible and a large unit was being developed. The silversides became well established in the lake and appeared to be a good control agent for the midge population, but there has been no attempt to quantify their effect on the phytoplankton. Other evaluations were either inconclusive or incomplete at this time. In addition to the aforementioned investigations, studies are being conducted to determine the nutrient sources and evaluate several possible control methods. **REFERENCES**: Brown (pers. comm.; annual reports are available), Cook, Jr. and Moore (1970), Goldman (1968), Horne (pers. comm.; reports are available), Horne (1972), Prine (pers. comm.), Sabanas et al. (1970), Weddell (pers. comm.; reports are available).

LAKE NAME: Clear Lake
LOCATION: northeastern Louisiana, USA
SURFACE AREA: 46.6 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundant population of trashfish. Gizzard shad *(Dorosoma cepedianum)* comprise about 90% by weight of the fish standing crop. **RESTORATION OBJECTIVE**: To evaluate experimental fish management practices, esp. the effect of trashfish removal by seining, on the fish population and sport fishery. **RESTORATION METHODOLOGY**: In the winter and spring of 1953–54 about 195 kg/ha of gizzard shad were removed; during the winter and spring of 1954–55 about 46 kg/ha were removed; and about 12.3 kg/ha, in the spring of 1956. A total of 41.5, 6.7, and 1.7 kg/ha were also removed for buffalo (*Ictiobus* spp.), gar (*Lepisosteus* spp.), and other species, respectively. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The study started in September, 1953 and ended in August, 1958. Removal was followed by a greatly increased production of young largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis* spp.), and other panfish during the first two summers. Bass fishing improved but not crappie fishing. The panfish population became overcrowded; although more panfish were caught/man-hour of effort, the weight caught/man-hour decreased considerably. **REFERENCES**: Lambou and Stern, Jr. (1958).

LAKE NAME: Clear Lake
LOCATION: Le Sueur Co., Minnesota, USA
SURFACE AREA: 1.1 km^2
MAXIMUM DEPTH: 6.7 m

PROBLEM: Overabundant trashfish populations. **RESTORATION OBJECTIVE**: To determine the effect of partial removal on the trashfish and gamefish populations. **RESTORATION METHODOLOGY**: Removal by seining began in the winter of 1953–54 and ended in 1957–58. The weight of trashfish removed varied from 241 kg/ha (138.5 kg/ha of carp, *Cyprinus carpio*) in 1953–54 to 0.8 kg/ha in 1955–56. The gamefish investigation started in the summer of 1953 and ended in 1957. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The black crappie (*Pomoxis nigromaculatus*) was the dominant gamefish. Year-class strength varied greatly during the period of trashfish removal, but the fluctuations did not seem to be directly associated with the quantity of trashfish removed. Changes in the growth rate of the crappies could not be related to the intensity of removal. The composition of the carp catch shifted from 13% juveniles in 1953–54 to 92% in 1957–58. **REFERENCES**: Scidmore and Woods (1961).

LAKE NAME: Clear Lake
LOCATION: Sawyer Co., Wisconsin USA
SURFACE AREA: 31 ha
MAXIMUM DEPTH: 9.8 m

PROBLEM: Overabundant, slow-growing bluegill (*Lepomis macrochirus*). **RESTORATION OBJECTIVE**: To evaluate predator stocking as a bluegill control practice. **RESTORATION METHODOLOGY**: In 1959, 5748 walleyes (*Stizostedion vitreum*, 185/ha) were stocked in the lake; these ranged in size from 7.6 to 22.8 cm. Muskellunge (*Esox masquinongy*), 20.3 to 30.5 cm in length, were stocked in 1960 (365 fish) and 1961 (300 fish). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Population estimates were not made; bluegills comprised 85–95% of the fish taken during surveys. Bluegill year-class strength varied in an apparent two year cycle. The stocked muskellunge exhibited above average growth and survival while walleye survival appeared to be poor. No significant changes in growth rate of bluegills were noted during the study period, 1959–1967. **REFERENCES**: Snow (1968).

LAKE NAME: Cliff Pond
LOCATION: Barnstable Co., Massachusetts, USA
SURFACE AREA: 78 ha
MAXIMUM DEPTH: 26.8 m

PROBLEM: Overabundant yellow perch *(Perca flavescens)* population. **RESTORATION OBJECTIVE**: To eliminate part of the population. **RESTORATION METHODOLOGY**: Emulsifiable rotenone (5%) was used to give an epilimnetic concentration of 0.2 mg/l. The lake was treated by spray application in August, 1956. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 48.2 kg/ha of dead fish were recovered, approximately 50% of these (by weight) were yellow perch. Chemical studies showed that the rotenone did not penetrate the thermocline; the population of cold water fish species was unaffected by treatment. About 16.8 kg/ha of the dead were brown bullheads *(Ictalurus nebulosus)*. Netting operations indicated that the fish had been eliminated from the epilimnion. It was estimated that 70–85% of the total standing crop had been removed from the lake. **REFERENCES**: Tompkins and Mullan (1958).

LAKE NAME: Cline's Pond
LOCATION: Polk Co., Oregon, USA
SURFACE AREA: 0.4 ha
MAXIMUM DEPTH: 4.9 m

PROBLEM: Eutrophic; dense populations of blue-green algae. Severe hypolimnetic oxygen depletion during summer stratification. **RESTORATION OBJECTIVE**: To determine the effect of aeration/circulation on the quantity and quality of the phytoplankton. To determine the effect on the oxygen and dissolved nutrient regimes. **RESTORATION METHODOLOGY**: The pond was partitioned off into experimental and control sections with plastic sheeting. Compressed air was introduced into the experimental section through four 12-m lengths of perforated tubing lying on the pond bottom for a period of about two months during the summer of 1969. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Thermal destratification occurred in the test section within three days, whereas the control section remained stratified throughout the test. Total phosphate concentrations were not affected significantly, although orthophosphate increased following destratification and again decreased after several weeks. No appreciable affect on nitrogen levels, specific conductance, total alkalinity, or total inorganic carbon was observed, but transparency was almost always greater in the test section during the study period. Chlorophyll *a* concentrations in the test section were uniform, averaging about 20 mg/m^3, whereas the concentrations in the control section varied with depth and were as high as 110 mg/m^3 in the upper waters. Total numbers of phytoplankton declined in the test section following destratification, although a large population of the green flagellate *Trachelomonas* developed later and predominated at all depths. In the control section *Trachelomonas* and a blue-green, *Anabaena*, occurred in bloom proportions. Destratification greatly enhanced the aesthetic appearance of the test section. **REFERENCES**: Malueg et al. (1971).

LAKE NAME: Cline's Pond
LOCATION: Polk Co., Oregon, USA
SURFACE AREA: 0.4 ha
MAXIMUM DEPTH: 3.7 m

PROBLEM: Highly eutrophic; hypolimnetic oxygen depletion during the summer. Conditions result from nutrients contained in introduced fish food and in drainage waters from the surrounding farmland. **RESTORATION OBJECTIVE**: To eliminate the excessive algal growth and to maintain an increased oxygen content throughout the summer through nutrient inactivation/precipitation. **RESTORATION METHODOLOGY**: The pond was treated in April, 1971. A floc of aluminum hydroxide was achieved using sodium aluminate at a rate of 10 mg Al/l of water. However, the aluminate was first neutralized to pH 7.0 with hydrochloric acid, because the water in the pond was very soft and unbuffered. The materials cost $500 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment decreased the degree of eutrophy. Phosphorus (orthophosphate and total phosphorus), total Kjeldahl nitrogen, ammonia, silica, iron, manganese, phytoplankton, chlorophyll *a*, and suspended solids were lowered. Transparency was greater, pH less variable, and oxygen remained more constant, near 100% saturation. No salmonid kills were experienced after treatment and fish were not affected by the treatment. A change was noted in algal species; and tests utilizing the Algal Assay Procedure indicated a temporary reduction in the growth potential. **REFERENCES**: Gahler (pers. comm.), Gahler et al. (in prep.), Sanville (pers. comm.).

LAKE NAME: Cobbett's Pond
LOCATION: Rockingham Co., New Hampshire, USA
SURFACE AREA: 1.2 km^2
MAXIMUM DEPTH: 18.3 m

PROBLEM: Nuisance growth of *Stigonema* on the bottom. **RESTORATION OBJECTIVE**: To control the *Stigonema* and rehabilitate the bathing area using $KMnO_4$. **RESTORATION METHODOLOGY**: Treatment occurred on three occasions: (1) August, 1971; 100 kg of $KMnO_4$, (2) July, 1972; 87 kg of $KMnO_4$, and (3) August, 1972; 50 kg of $KMnO_4$. The chemical costs were about $55 USA/kg. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment provided temporary control of *Stigonema* during periods of nuisance growth. **REFERENCES**: Frost (pers. comm.).

LAKE NAME: Cochrane
LOCATION: Vilas Co., Wisconsin, USA
SURFACE AREA: 51 ha
MAXIMUM DEPTH: 3.4 m

PROBLEM: Eutrophic; excessive growth of macrophytes. **RESTORATION OBJECTIVE**: To reduce the nutrient input by controlling the raw sewage and septic tank effluents. **RESTORATION METHODOLOGY**: Since project initiation in 1970, residents along the shoreline have been required to install their septic systems and seepage beds away from the lake. The project is 50% completed. In addition, intensive harvesting of macrophytes (esp. *Potamogeton* spp.) was started in late summer, 1972. Artificial aeration may be practiced after cessation of the input of sewage effluent. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During 1972 approx. 7.3×10^4 kg of macrophytes were harvested. As of November, 1972 no significant changes in dissolved oxygen content, nitrate, phosphate, alkalinity, transparency, etc. were noted. Studies will, however, continue. **REFERENCES**: Crabtree (pers. comm.).

LAKE NAME: Collins Pond
LOCATION: southern USA
SURFACE AREA: 1.6 ha
MAXIMUM DEPTH: 2.9 m

PROBLEM: Overcrowded, slow-growing panfish; unbalanced fish population. **RESTORATION OBJECTIVE**: To test the effectiveness of a new piscicide–antimycin–for thinning the overabundant species. **RESTORATION METHODOLOGY**: The liquid formulation of antimycin, Fintrol–Concentrate, was used in the shallow area of the pond. About 36.5% of the pond was treated on 24 June, 1968 at a concentration of 1.0 µg/l. The toxicant was spilled on the pond surface in front of a moving boat. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 114 kg of panfish and 0.17 kg of small largemouth bass *(Micropterus salmoides)* were removed/ha. The panfish were composed of 81.5% fish under 12.7 cm in length. The high kill of larger panfish was due to treatment during a period of nesting activity. **REFERENCES**: Burress (1970).

LAKE NAME: Conesus

LOCATION: Livingston Co., New York, USA
SURFACE AREA: 13.4 km^2
MAXIMUM DEPTH: 18 m

PROBLEM: Eutrophic conditions due to the influx of sewage, detergents and natural runoff. Heavy plankton blooms of blue-green algae and excessive macrophytes. Local fecal pollution (some input streams and near septic tanks). Destruction of wet shorelands and encroachment by filling have also been problems. **RESTORATION OBJECTIVE**: To reduce the nutrient input to the lake and to reduce algal blooms. To restore the recreational aspects of the lake. **RESTORATION METHODOLOGY**: A perimeter sewer is being constructed for diversion of septic tank and municipal effluent. Diversion from the lake is to a plant with advanced (phosphate reduction) treatment; the effluent will be discharged into the lake's outlet stream. The cost of the project will be $4,739,095 USA. It is scheduled to be operative sometime in 1973. In addition, phosphate detergent usage will be banned as of June, 1973. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The project is under construction so no information is available at this time. Several limnological parameters are under study. The lake is known to be phosphorus limited. **REFERENCES**: Child and Oglesby (1970), Child et al. (1971), Forest (pers. comm.), Forest and Mills (1971), Oglesby (pers. comm.), Savard and Bodine (1971), Walker (pers. comm.).

LAKE NAME: Conneaut Lake

LOCATION: northwestern Pennsylvania, USA
SURFACE AREA: 3.8 km^2
MAXIMUM DEPTH: 18.3 m

PROBLEM: Overabundance of macrophytes. **RESTORATION OBJECTIVE**: To limit the macrophyte growths. **RESTORATION METHODOLOGY**: The areas with dense macrophyte growths were treated with herbicides–diquat and endothall. The approximate cost was $74 to $86 USA/ha treated. Approximately 74 ha were treated. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment effectively reduced the macrophytes by about 50%. This varied, however, with depth. *Myriophyllum* sp., *Najas* sp., *Potamogeton* sp., and *Elodea canadensis* were controlled with the herbicides. **REFERENCES**: Wohler (pers. comm.).

LAKE NAME: Lake Conway

LOCATION: Faulkner Co., Arkansas, USA
SURFACE AREA: 27.1 km^2
MAXIMUM DEPTH: 3.7 m

PROBLEM: Overabundance of macrophytes, submergent and emergent types. **RESTORATION OBJECTIVE**: To convert the macrophytes into useful fish flesh; to provide more fishable water for sportsmen; and to provide food. **RESTORATION METHODOLOGY**: The white amur or grass carp *(Ctenopharyngodon idella)*, an herbivorous fish species was introduced in December, 1971. This stocking was at a rate of 7.4 fish/ha, but when more fish become available it will be increased to 17–41/ha. Fish rearing costs are about $5 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Small areas of macrophytes are beginning to disappear, but it is too early for the desired degree of control. Complete control of the submergents is anticipated within three years. **REFERENCES**: Bailey (pers. comm.), Bailey (1972).

LAKE NAME: Lake Corpus Christi

LOCATION: Texas, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of water hyacinths *(Eichornia crassipes)*. **RESTORATION OBJECTIVE**: To treat the macrophytes with an herbicide. **RESTORATION METHODOLOGY**: A small area (20 ha) of extremely dense growth was chosen for demonstration using a new water-in-oil emulsion of 2,4-D. On 10-11 May, 1963 the herbicide (0.12 kg acid equivalent/l) was applied by helicopter at a rate of 1.9 l of herbicide/13.3 l of water/ha. Application required about 2.5 hrs and was slightly more than twice as expensive as the conventional surface-craft type of application. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Four days after the application, water hyacinths began to wilt. After about 11 days, some of the hyacinths turned yellow. Within five weeks, nearly two-thirds of the hyacinths were badly wilted but others were apparently recovering. Two months after the application most of the hyacinths were still alive. No herbicide drift occurred during application; therefore the poor success was attributed to the extremely dense growths, 0.3 to 0.9 m high, in the demonstration area. **REFERENCES**: Menn (1965).

LAKE NAME: Cox Hollow Lake

LOCATION: Iowa Co., Wisconsin, USA
SURFACE AREA: 39 ha
MAXIMUM DEPTH: 8.8 m

PROBLEM: Highly eutrophic conditions; summer hypolimnetic oxygen depletion; nuisance algal growths; and high surface water temperatures. Poor fish growth and reproduction; and sharply declining sport fishery. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen levels during both summer and winter. To limit algal abundance. **RESTORATION METHODOLOGY**: In July, 1966, six 3.6 m long "Aero-Hydraulic Guns" were installed in the deepest area in order to destratify the lake and oxygenate the bottom water. Air was supplied to the guns by two electrically-powered compressors, each rated at 34 l/sec. The guns transferred about 2400 l/sec of water from the lake bottom to the surface. In 1967 the guns were replaced with three 1.5 m long "Helixors", which have been in operation to the present. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Both systems were successful in eliminating thermal and chemical stratification, although minor gradients sometimes developed. Total phosphate, Kjeldahl nitrogen, iron, and manganese concentrations decreased, but nitrate and nitrite nitrogen concentrations increased during aeration. Benthic macroinvertebrates quickly became established in the profundal zones, but fish populations did not exhibit a substantial response, despite increased habitat and available food. Algal problems were not eliminated, but the blooms decreased in severity. Operation of the aeration system in the winter maintained dissolved oxygen levels well above the critical levels which had existed in previous years. **REFERENCES**: Brezonik et al. (1969), Wirth and Dunst (1967), Wirth et al (1970).

LAKE NAME: Creve Coner Lake

LOCATION: St. Louis Co., Missouri, USA
SURFACE AREA: 99 ha
MAXIMUM DEPTH: 0.8 m

PROBLEM: Rapid accumulation of excessive quantities of silt from the Missouri River. The lake has experienced a 60 ha reduction in the surface area since 1900 and is currently losing area at a rate of about 8 ha/yr. About 74,000 m^3 of sediment are deposited in the lake annually. **RESTORATION OBJECTIVE**: To remove the silt and clay from the lake bottom and to control the future influx of sediment. To develop a land and water oriented county-owned recreational facility. **RESTORATION METHODOLOGY**: A 36 cm hydraulic cutterhead dredge will be used to remove bottom sediments. A minimum depth of 1.5 m is envisioned, and the lake may be dredged to a depth of 3 m. Depending on funds available, the lake may be enlarged by up to 30 ha. Unit costs of about \$0.80 USA/m^3 are planned, using a county-owned dredge run by county employees. Spoils will be used to increase the elevation of shoreline areas to reduce flooding. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available; operation of the dredge will probably begin in 1973 or 1974. **REFERENCES**: R. W. Booker and Assoc., Inc. (1971), Gilbert (pers. comm.).

LAKE NAME: Crystal Lake
LOCATION: Lake Crystal, Minnesota, USA
SURFACE AREA: 1.6 km^2
MAXIMUM DEPTH: 4.5 m

PROBLEM: Excessive nutrient and sediment influx. Winter dissolved oxygen depletions; fishkills; and nuisance algal growth. **RESTORATION OBJECTIVE**: To minimize the winterkills and to reduce algal production. **RESTORATION METHODOLOGY**: A used dredge was purchased and outfitted at a cost of about \$50,000 USA. Operation began in 1970. Spoils are discharged to a diked-off area in a shallow bay contiguous to the lake. Annual cost of the operation is about \$25,000. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The rate of sedimentation is nearly equal to the production of the dredge and there has been no noticeable improvement in lake water quality. Presumably deterioration has been arrested, however, and the spoils have been used for considerable economic value. **REFERENCES**: Henney (pers. comm.).

LAKE NAME: Daggett
LOCATION: Barry Co., Michigan, USA
SURFACE AREA: 5 ha
MAXIMUM DEPTH: 4.6 m

PROBLEM: Excessive numbers of small bluegills *(Lepomis macrochirus)*. **RESTORATION OBJECTIVE**: To determine the ability of predator fish species to control the numbers of small bluegills. **RESTORATION METHODOLOGY**: Prior to the study all of the fish in the lake were eliminated using rotenone; bluegill only populations were re-established. In July, 1963, 45 kg of adult bluegills were stocked; these reproduced well. During 1964–66, 675 northern pike *(Esox lucius)* were stocked each year. In September, 1966 rotenone was used to evaluate population characteristics. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Survival of the first northern pike stocking was 44%, while survival of succeeding stocks was only 1.5 to 2.7%. The growth rate of northern pike was below the state average. Bluegill abundance was not controlled. In September, 1966 bluegills under 10 cm numbered 40,081/ha and growth averaged 7.4 cm less than the state average. **REFERENCES**: Beyerle (1970).

LAKE NAME: Davis
LOCATION: Chickasaw Co., Mississippi, USA
SURFACE AREA: 75 ha
MAXIMUM DEPTH: 6.1 m

PROBLEM: Nuisance densities of aquatic vegetation, primarily *Chara* and *Najas*. Apparently caused by shallow, unusually clear water. **RESTORATION OBJECTIVE**: To reduce the vegetation abundance in order to enhance fishing, swimming, and other recreational uses. **RESTORATION METHODOLOGY**: The herbivorous grass carp *(Ctenopharyngodon idellus)* was stocked at the rate of approx. 5 fish/ha–average size of 0.9–1.4 kg. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Vegetation control is not evident as yet because of the low fish population density. **REFERENCES**: Avault, Jr.;Bailey and Boyd [?]; Gibbs (pers. comm.); Lawrence [?].

LAKE NAME: Dead Lakes
LOCATION: Gulf and Calhoun Cos., Florida, USA
SURFACE AREA: 20.2 km^2
MAXIMUM DEPTH: 7.6 m

PROBLEM: Macrophyte infestations: Eurasian water milfoil *(Egeria)*, milfoil *(Myriophyllum)* and coontail *(Ceratophyllum)*. **RESTORATION OBJECTIVE**: To control the macrophytes; to improve the fish catchability; to consolidate the bottom sediments; and to improve the water quality. **RESTORATION METHODOLOGY**: A water control structure is being constructed for \$300,000 USA. Drawdown will be timed to achieve optimal control of the problem macrophytes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not available at the present time. **REFERENCES**: Burkhalter (pers. comm.).

LAKE NAME: Deer Flat Reservoir
LOCATION: southwestern Idaho, USA
SURFACE AREA: 36.4 km^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundant carp *(Cyprinus carpio)* population. **RESTORATION OBJECTIVE**: To selectively remove the problem species with minimal damage to the rest of the fish population. **RESTORATION METHODOLOGY**: Rotenone (Pro-Noxfish) was applied to selected areas during the spawning period, 1958–61. Application was by airplane. A range of concentrations were used. For a 18 ha area the cost was \$174 USA/treatment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: At least 2 mg/l concentration was needed to kill the carp before they could move out of the treatment area. The areas detoxified in 2–7 days. Carp moved back into the spawning areas after detoxification and treatments could therefore be repeated successfully. In a 18 ha bay 90,000 to 105,000 carp were killed/treatment (average weight of 136,000 kg). The kill of gamefish was minor. **REFERENCES**: Richards (1962).

LAKE NAME: Deer Island
LOCATION: Orange Co., Florida, USA
SURFACE AREA: 2.2 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundant gizzard shad *(Dorosoma cepedianum)* population; poor quality sport fishery. **RESTORATION OBJECTIVE**: To reduce the shad population without injury to the gamefish by selective poisoning and seining. **RESTORATION METHODOLOGY**: A concentration of 0.1 mg/l emulsified rotenone (5%) was applied on 24 January, 1955. Rotenone was also applied on 9 March, 1955 at 0.15 mg/l and on 12 February, 1956 at 0.1 mg/l. Application was done by boat. Netting operations were conducted before and after chemical treatment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The first rotenone treatment resulted in an estimated kill of 950–1120 kg of shad/ha. No other species were killed. The smaller fish died first and were severely reduced numerically. Many dead fish were harvested by gulls and herons. The second treatment caused the death of additional shad (mostly larger in size); however, some largemouth bass *(Micropterus salmoides)*, 12.7–35.6 cm in length, also died. During the third treatment only one shad was recovered but large numbers of bass (14–63.5 cm) and bluegills *(Lepomis macrochirus*, 2.5–10 cm) were eliminated from the lake. The first treatment severely affected the shad population and the following treatments and netting operations appeared to effectively remove this species from the lake by early 1956. Successful gamefish reproduction was noted in 1955. **REFERENCES**: Huish (1957).

LAKE NAME: Delavan
LOCATION: Delavan, Wisconsin
SURFACE AREA: 8.4 km^2
MAXIMUM DEPTH: 17 m

PROBLEM: Noxious algal blooms; nutrient influx from agricultural runoff and sewage treatment plant and septic tank effluents. Few macrophytes present due to copper accumulation in the sediments (previous copper sulfate treatments in this hardwater lake resulted in rapid, extensive copper precipitation); nutrients were being channeled into algal growths. **RESTORATION OBJECTIVE**: To reduce the nuisance algal growths. **RESTORATION METHODOLOGY**: A chelated copper algicide (Cutrine) was applied at rates of 4.7–11.7 l of algicide/ha, depending on algal density. A barge and power spraying units were used. Six treatments were made in 1969 and eight in 1970. These ranged from marginal spraying of 28 ha to treatment of 243 ha of inshore and open waters. **RESULTS: (OR STATUS FOR ONGOING PROJECTS)**: The first four treatments succeeded in reducing the population density of *Anacystis*, a highly toxic form of planktonic algae, to nearly zero. The final treatments concentrated on other species. Although periodic maintenance will continue to be necessary, aesthetically desirable conditions were achieved following the 1970 treatments and some recurrence of macrophytes was observed. **REFERENCES**: American City Magazine (1971).

LAKE NAME: Devils Lake
LOCATION: Lincoln Co., Oregon, USA
SURFACE AREA: 2.4 km^2
MAXIMUM DEPTH: 8.5 m

PROBLEM: Gross sewage pollution, primarily from defective sewage treatment plant; high coliform count; dense algal blooms; and dense macrophyte growths. **RESTORATION OBJECTIVE**: To eliminate the influx of raw sewage. **RESTORATION METHODOLOGY**: In 1970 the sewage treatment plant was closed; and the sewage was piped out of the drainage basin. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: While the coliform count has been reduced, algae, siltation and macrophytes continue to be problems. Further work will be necessary for the restoration of this lake. **REFERENCES**: McHugh (pers. comm.), McHugh (1972).

LAKE NAME: Dewey Lake
LOCATION: Floyd Co., Kentucky, USA
SURFACE AREA: 4.5 km^2
MAXIMUM DEPTH: --

PROBLEM: Overabundance of gizzard shad *(Dorosoma cepedianum)*. **RESTORATION OBJECTIVE**: To reduce the population using a piscicide in concentrations that selectively kill the gizzard shad. **RESTORATION METHODOLOGY**: Rotenone was applied by boat and airplane in March, 1955. The lake was divided into sections and emulsifiable rotenone (Chem Fish) was added at a rate of 9.4 l/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The standing crop of shad was reduced from 114 to 35.5 kg/ha. The average catch of gamefish by angling decreased in 1955 while the catch rate for panfish increased. Rapid growth of young-of-the-year shad occurred in 1955. **REFERENCES**: Carter (1956).

LAKE NAME: Dewey Lake
LOCATION: Floyd Co., Kentucky, USA
SURFACE AREA: 4.5 km^2
MAXIMUM DEPTH: --

PROBLEM: Overabundant, slow-growing white crappies *(Pomoxis annularis)*. **RESTORATION OBJECTIVE**: To alleviate the intraspecific competition by removal of a part of the white crappie population. **RESTORATION METHODOLOGY**: During an overwinter drawdown (1962-63) both gill nets and trammel nets were used for fish removal. All fish except crappie and trashfish were returned to the lake. Removal occurred from early November to early December and for about two months the next spring. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Netting success was poor for white crappies. Only 1374 crappies were harvested; in 1954 the white crappie population was estimated at 97,000. The level of removal was considered insufficient to reduce the intraspecific competition. **REFERENCES**: Carter (1963).

LAKE NAME: Diamond Lake
LOCATION: Douglas Co., Oregon, USA
SURFACE AREA: 11.4 km^2
MAXIMUM DEPTH: 15.2 m

PROBLEM: Excessive late summer blue-green algal blooms. Excessive macrophyte growths. Occasional winterkills. Taste and odor problems in the fish flesh. Nutrient input primarily from campsites, summer homes, and a lodge. **RESTORATION OBJECTIVE**: To reduce the nutrient load in order to control algal blooms. **RESTORATION METHODOLOGY**: A sewage interceptor system was constructed to collect wastes from about one-half of the circumference of the lake. About three-fourths of the campsites are presently using the system. The interceptor system diverts the sewage to three treatment lagoons located outside the drainage basin of the lake. A lodge complex has not as yet been connected to the system but will be during 1973. Action is also being taken to terminate the leases of the summer cottages. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Physical, chemical and biological parameters have been studied for two years. Monitoring will continue several more years to determine if water quality changes result from the reduced nutrient inputs. If this proves less effective than desired, alternative treatment will be considered. **REFERENCES**: McHugh (pers. comm.), McHugh (1972), Sanville (pers. comm.; a report is in preparation).

LAKE NAME: Dion Lake
LOCATION: Rolette Co., North Dakota, USA
SURFACE AREA: 34 ha
MAXIMUM DEPTH: 6.4 m

PROBLEM: Shallow, eutrophic; periodic winterkills. **RESTORATION OBJECTIVE**: To prevent winterkill by improving the dissolved oxygen conditions. **RESTORATION METHODOLOGY**: An aeration system was installed in late fall, 1968 to aerate the lake. The system consisted of a small, shore-mounted compressor connected to a 305 m length of perforated tubing placed on the lake bottom. **RESULTS (OR**

STATUS FOR ONGOING PROJECTS): Although air was released only from the proximal part of the tubing due to improper sizing of the perforations, no winterkill was noted during the period of operation. However, the winters were characterized by abnormally high temperatures and low snowfall, so the effects of aeration were unclear. **REFERENCES**: Kreil (1971).

LAKE NAME: Lake Diversion
LOCATION: Texas, USA
SURFACE AREA: –
MAXIMUM DEPTH: –

PROBLEM: Overabundant trashfish population, especially gizzard shad *(Dorosoma cepedianum)* and freshwater drum *(Aplodinotus grunniens)*. **RESTORATION OBJECTIVE**: To selectively eliminate the problem species thereby benefiting the gamefish populations. **RESTORATION METHODOLOGY**: In March, 1957 the lake was treated with 5% rotenone powder. Application was by boat. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The killed fish were mostly gizzard shad and freshwater drum; gamefish constituted only a small percentage. Based on pre–and post-treatment netting, the shad population was reduced by 80% but repopulated the lake within three years. Other fish species were little effected by the treatment; however, the condition of all species of gamefish increased after treatment. Although the lake was usually moderately clear, rotenone treatment resulted in increased clarity. Some of the bottom fauna were greatly reduced, especially the Ephemeroptera (mayflies). **REFERENCES**: Peters (1961).

LAKE NAME: Dollar
LOCATION: Rifle River area, Michigan, USA
SURFACE AREA: 5.2 ha
MAXIMUM DEPTH: 4.6 m

PROBLEM: Dense population of slow growing bluegills *(Lepomis macrochirus)*. **RESTORATION OBJECTIVE**: To improve fish growth and angling through population reduction. **RESTORATION METHODOLOGY**: In May, 1959 bluegills were removed by seining. The standing crop of 10.2–12.7 cm bluegills was reduced by 68%. Removal of other size groups was negligible. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During 1959, four-year-old bluegills (comprised mostly 10.2 to 12.7 cm fish) improved their growth rate by 30%. The other age groups were unaffected and improvement in growth for the four-year-olds occurred only in 1959. Fishing success and catch declined drastically following the removal operation. Interpretation of the data was complicated by a spurt in bluegill growth in 1958, high mortality of the 1952 year-class, and weak succeeding year-classes. **REFERENCES**: Patriarche (1963b).

LAKE NAME: Duck Pond
LOCATION: near Groton, Massachusetts, USA
SURFACE AREA: 11.3 ha
MAXIMUM DEPTH: –

PROBLEM: Poor quality sport fishery. **RESTORATION OBJECTIVE**: To improve the gamefish populations by selectively removing the overabundant panfish and trashfish. **RESTORATION METHODOLOGY**: Thinning operations were carried out using fyke nets. Removal amounted to 49.3 and 31.4 kg/ha in 1953 and 1954 respectively. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In 1953 about 37% by weight of the catch was brown bullheads *(Ictalurus nebulosus)*; 21% was lake chubsuckers *(Erimyzon)*; and 20%, yellow perch *(Perca flavescens)*. In 1956 about 56% was brown bullheads. There didn't seem to be any change in the gamefish population. The average size of the brown bullheads increased from 18 cm in 1953 to 25.7 cm in 1956. There was an increase in rate of growth for bluegills *(Lepomis macrochirus)* and yellow perch. **REFERENCES**: Grice (1958).

LAKE NAME: Eagle
LOCATION: Kandiyohi, Minnesota, USA
SURFACE AREA: 3.6 km^2
MAXIMUM DEPTH: 15.3 m

PROBLEM: Algal blooms and overabundant macrophytes due to an excess of nutrients. **RESTORATION OBJECTIVE**: To restore the aesthetic and recreational value of the lake through control of sewage and agricultural runoff. To test new ideas and provide findings and recommendations with general applicability. **RESTORATION METHODOLOGY**: A peripheral sewage collection system was constructed to divert the effluents of individual septic tank systems (about 250 homes). This was completed at a cost of $600 000-800,000 USA. Three experimental water detention structures were also built to control the nutrient influx from agricultural runoff. This was completed at a cost of about $47,000. Both installations were finished by November, 1972. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Two years of lake water quality data were gathered prior to treatment. Future research will assess the efficacy of the control measures through limnological, hydrologic, and socio-economic studies of the lake, drainage basin, and local community. **REFERENCES**: Kandiyohi County Board of Commissioners (1971), Reinarz (pers. comm.), Straw (pers. comm.), Swanson (pers. comm.).

LAKE NAME: East Pond
LOCATION: near Three Forks, Montana, USA
SURFACE AREA: 5.2 ha
MAXIMUM DEPTH: 3.7 m

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To determine some of the changes in limnology that result from the usage of toxicants in fisheries management. **RESTORATION METHODOLOGY**: An emulsified solution of 60% toxaphene was applied in July, 1957 for an average concentration of 0.13 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Observations and netting operations revealed no fish one month after treatment. The recovered, dead fish yielded 87.8 kg/ha, 60.6% carp *(Cyprinus carpio)*. After treatment water clarity increased from less than 1.5 m to the bottom; turbidity decreased from 8.2 mg/l to less than 1.0 mg/l; and D.O., phenolphthalein alkalinity, and pH increased while MOA decreased. There was no change in nitrates or phosphates. Phytoplankton abundance was reduced by treatment, esp. *Dinobryon* and *Ceratium*. Toxaphene eliminated the Cladocera, Copepoda, Ostracoda, and Protozoa; Rotifers were greatly reduced but not eliminated. Odonata was not found after treatment; Gastropoda was reduced but not eliminated. **REFERENCES**: Wollitz (1962).

LAKE NAME: East Okoboji Lake
LOCATION: Dickinson Co., Iowa, USA
SURFACE AREA: 5.7 km^2
MAXIMUM DEPTH: 7.9 m

PROBLEM: Overabundant population of trashfish and relatively few gamefish. **RESTORATION OBJECTIVE**: To improve the gamefish population through an intensive trashfish removal program (more intensive than normally conducted). **RESTORATION METHODOLOGY**: Trashfish were removed by seining and trapnetting primarily in spring and fall; and by some gill-netting in winter during 1940–51. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The years 1940–43 were the most productive in kg/ha of trashfish *(Cyprinus carpio; Aplodinotus grunniens,* and *Ictiobus* spp.*)* removed. The average catch in weight of trashfish per seine haul declined significantly during the study period; however, this was due to a decrease in buffalo (*Ictiobus* sp.). The catch per effort of carp *(Cyprinus carpio)* actually decreased. The average catch in numbers and weight of gamefish per seine haul increased significantly during the study period. Test seining also revealed a significant increase in young-of-the-year as well as adult gamefish by the end of the study. Macrophytes became abundant in the lake and there was some problem due to excessive growth. **REFERENCES**: Rose and Moen (1952).

LAKE NAME: El Capitan Reservoir
LOCATION: San Diego Co., California, USA
SURFACE AREA: 17 km^2
MAXIMUM DEPTH: 62 m (full pool)

PROBLEM: Hypolimnetic oxygen depletion with a concomitant increase in anaerobic decomposition products and the exclusion of fish and other organisms from the profundal zone. **RESTORATION OBJECTIVE**: To increase the dissolved oxygen concentration in the bottom waters during the summer in order to improve the water quality and enlarge the fish habitat. **RESTORATION METHODOLOGY**: The destratification system consisted of a 31 m length of perforated tubing in the deepest part of the reservoir connected to an electric air compressor rated at 101 l/sec, 8.8 kg/cm^2. The capital and installation costs of the system were $6,010 USA. Amortization of this cost over a 10-year period, plus power and maintenance costs, gave an annual cost of about $3,000. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Complete destratification was achieved during the summers of 1965 and 1966. During destratification, the temperature of the entire lake increased to approximately the same level as the epilimnetic temperatures during normal stratification. Dissolved oxygen was distributed to all depths but the surface concentrations were lower due to accelerated oxygen uptake. Aeration greatly decreased the iron, manganese, and hydrogen sulfide concentrations in the deeper waters without a substantial increase in the surface waters. Total phosphate concentrations and conductivity were also reduced. Destratification distributed zooplankton throughout the lake; however, they concentrated near the aerator and were subject to heavy predation by fish. Benthic organisms rapidly invaded the profundal zone during the period of destratification, and the total numbers in the lake dramatically increased. The increase in food organisms and habitat was probably beneficial to fish populations but detailed studies were not conducted. **REFERENCES**: Fast (1968, 1971b), Inland Fisheries Branch (1970).

LAKE NAME: Emerald
LOCATION: Calhoun Co., Michigan, USA
SURFACE AREA: 2.3 ha
MAXIMUM DEPTH: 2.7 m

PROBLEM: Excessive numbers of small bluegills *(Lepomis macrochirus)*. **RESTORATION OBJECTIVE**: To determine the ability of predator fish species to control the numbers of small bluegills. **RESTORATION METHODOLOGY**: Prior to the study all of the fish in the lake were eliminated using rotenone; only bluegill populations were re-established. The lake was stocked in March, 1966 with 11 kg of adult bluegills and 11 kg of juveniles (5–8 cm in length). From 1966 through 1968, 250 fingerling northern pike *(Esox lucius)* were stocked each year. In September, 1968 the fish population was analyzed after rotenone treatment. During 1966–68 the lake was treated successfully with herbicides once each summer. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Survival of the first stocking of northern pike was 60%, while survival of succeeding stocks was only 0.8 to 9.2%. The growth rate of northern pike was below the state average. Bluegill abundance was not controlled. In September, 1968 bluegills under 10 cm numbered 14,360/ha and growth averaged 3.3 to 3.8 cm less than the state average. **REFERENCES**: Beyerle (1970).

LAKE NAME: Eola
LOCATION: Orange Co., Florida, USA
SURVACE AREA: 11 ha
MAXIMUM DEPTH: 7.6 m

PROBLEM: Increasingly eutrophic; declining aesthetic and recreational appeal. Continuous bloom of blue-green algae and a buildup of organic sediments on the lake bottom. **RESORATION OBJECTIVE**: To control the blue-green algal growth and to remove the near-shore organic sediment accumulations. **RESTORATION METHODOLOGY**: Lake drawdown (3.1 m) was achieved with the use of several 120 m deep drainage wells and pumps. Approximately one-half of the lake bottom was exposed for four months during the summer of 1972. During drawdown trashfish were removed from the lake and urban runoff was given primary treatment. Also, in the near shore areas about 38,000 m^3 or organic sediments were removed with conventional excavation equipment and 61,000 m^3 of sand were deposited. Storm sewer improvements, pumps, and water sampling programs cost about $11,000 USA, whereas the cost of the near shore alterations approximated $20,000-30,000. Future siltation will be reduced by a more extensive street cleaning program. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Sand blanketing and sediment and trash removal greatly enhanced the aesthetic appeal. Drawdown also increased the stability of the remaining lake sediments. Information regarding the amount of sediment consolidation, the effect of drawdown and restoration measures on water quality, and changes in the fish population are not available at the present time. **REFERENCES**: Alt (pers. comm.), Florida Technological University and Orange County Pollution Control Department (1972), Sheffield (pers. Comm.), Sheffield and Bishop (1973).

LAKE NAME: Escondido Reservoir
LOCATION: Escondido, California, USA
SURFACE AREA: 1 km^2
MAXIMUM DEPTH: 13 m

PROBLEM: Hypolimnetic oxygen depletion; taste and odor problems due to hydrogen sulfide. Used as a water supply reservoir; high chlorine dosage necessary during pre-usage treatments. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen content of the bottom waters in order to provide a dependable, year-round water supply. **RESTORATION METHODOLOGY**: An aeration/circulation system was installed to eliminate thermal stratification. Air was introduced near the bottom of the reservoir through 18 m of perforated plastic tubing connected to a shore-mounted air compressor rated at 99 l/sec, 7 kg/cm^2. During periods of stratification, the compressor was run about 34 hours, twice/week. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Prior to destratification, the temperature was about 8^o C lower at the bottom than at the surface. With the system operating, the temperature differential was less than

0.5° C. Chlorine dosages decreased by more than one-third, and the hydrogen sulfide and bacteria concentrations were noticeably reduced. The savings in chlorine alone reportedly paid for the aeration system in one year. **REFERENCES:** Burns (1966), Industrial Water Engineering (1966), McCullough (1971).

LAKE NAME: Lake Eucha
LOCATION: Delaware Co., Oklahoma, USA
SURFACE AREA: 11.7 km^2
MAXIMUM DEPTH: --

PROBLEM: Possible development of a poor quality sport fishery and fish population. **RESTORATION OBJECTIVE:** To maintain the existing status through a trashfish removal program. **RESTORATION METHODOLOGY:** Water level fluctuations occurred during the study period. During 1953–64 21,748 kg of trashfish were removed by gill netting and seining. A creel census was started in September, 1954. Age-growth data was collected through the study period except for 1959–62. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Growth rates have generally declined (typical of new impoundments like Lake Eucha) but remain above the state average. Although there were some fluctuations, the sport fishery was satisfactory during the management period. **REFERENCES:** Jackson, Jr. (1966).

LAKE NAME: Eufaula Reservoir
LOCATION: Oklahoma, USA
SURFACE AREA: 415 km^2
MAXIMUM DEPTH: 27 m (power pool elevation)

PROBLEM: Water quality problems resulting from thermal stratification and hypolimnetic oxygen depletion. **RESTORATION OBJECTIVE:** To demonstrate the practical application of the destratification technique and to develop design criteria for use elsewhere. **RESTORATION METHODOLOGY:** Air was introduced at the bottom of the reservoir with a cross-shaped diffuser system incorporating 16 porcelain microporous diffusers. In 1967, two diesel-powered roto-screw air compressors rated at 71 l/sec each were used to supply air. In 1968, an electrically-powered roto-screw compressor rated at 570 l/sec was used to supply air to a larger diffuser system which incorporated 48 microporous diffusers. Aeration commenced in July, 1967 and ceased 25 days later. In 1968, the compressor was operated for 32 days during August and September. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Although the 1967 system was undersized, the 4 mg/l dissolved oxygen level dropped from the 9 m depth to 13 m. Fish, normally present in maximum depths of 5.5 to 7.6 m were found in depths up to 15 m after aeration. The effects of aeration extended as far as 4 km upstream from the diffusers. In 1968, power releases from the dam greatly modified the effects of the system. The 4 mg/l dissolved oxygen level reached the bottom of the reservoir near the dam but was 9 m above the bottom at the diffusers. The dissolved oxygen concentration in the discharge waters increased from 3 mg/l before aeration to 4.0–5.5 mg/l depending on the volume of power releases. The temperature of the discharge water increased from 24 to 25.7° C. Aeration had no apparent effect on the zooplankton community in the central pool of the reservoir. Oxygen added to the discharge waters cost approximately $6.00 USA/1000 kg, based on power costs alone. **REFERENCES:** Bowles (undated), Leach (pers. comm.), Leach (1968), Leach et al. (1968, 1970), Wood and Leach (1969).

LAKE NAME: Fall Hollow
LOCATION: Navajo Co., Arizona, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Heavy algal blooms caused by the influx of municipal sewage treatment plant effluent. **RESTORATION OBJECTIVE:** To reduce the algal blooms by removing the nutrient input. **RESTORATION METHODOLOGY:** The municipal sewage plant effluent is being pumped out of the drainage basin following secondary treatment. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Results are still under study. Already the phosphorus levels have been reduced by nearly one-half. Plankton blooms have not been effected as yet. The nutrient content in the lake is still high. **REFERENCES:** Rathbun (pers. comm.).

LAKE NAME: Falmouth Lake
LOCATION: Kentucky, USA
SURFACE AREA: 91 ha
MAXIMUM DEPTH: 13 m

PROBLEM: Hypolimnetic oxygen depletion during the summer. Used as a municipal water supply. **RESTORATION OBJECTIVE:** To study destratification as a means of improving the bottom water quality. **RESTORATION METHODOLOGY:** The lake was destratified during the summer of 1966 with compressed air released through 16 porous ceramic diffusers placed in a cross pattern on the lake bottom. Air was supplied with a compressor that delivered 54 l/sec at 2.1 to 2.8 kg/cm^2. Aeration began in May, and the compressor was operated for six separate four to eight day periods until September. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The oxygen balance–expressed as the dissolved oxygen content minus the oxygen demand of the reduced forms of iron, manganese, and sulfide–was less than zero for July and August. Because of heavy fertilization to increase fish production, the oxygen demand was high; however, continuous aeration/mixing may have prevented the buildup of reduced materials, as indicated by decreases in concentration during the periods of operation. During three of the mixing periods, plankton counts at the 1.5 m depth increased, but substantial declines were noted during two periods. Total standing crop decreased during three of the periods; shifts in algal populations away from blue-greens were observed during these periods. **REFERENCES:** Symons et al. (1967b, 1970).

LAKE NAME: Fish Lake
LOCATION: Sevier Co., Utah, USA
SURFACE AREA: 10.9 km^2
MAXIMUM DEPTH: 48.8 m

PROBLEM: Rapid increase in algae over the past five years, apparently induced by sewage seepage into the lake. **RESTORATION OBJECTIVE:** To improve the water quality by decreasing the inflow of sewage. To reduce the algal growth to natural levels. **RESTORATION METHODOLOGY:** The sewage will be collected and taken away from the lake via pipeline. The estimated cost of the project is $850,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Pipeline construction has just started. Completion of the project is expected in summer, 1974. **REFERENCES:** Thomas (pers. comm.).

LAKE NAME: Flathead

LOCATION: Lake and Flathead Cos., Montana, USA

SURFACE AREA: 518 km^2

MAXIMUM DEPTH: 111.3 m

PROBLEM: Increasing eutrophication due to fruit farming, industry, logging, and municipal development. **RESTORATION OBJECTIVE**: To prevent further eutrophication of this oligotrophic, phosphate limited lake. To maintain or improve the water quality by encouraging better land management practices and urban sewage treatment. **RESTORATION METHODOLOGY**: Municipal tertiary sewage treatment plants are being built and/or planned. A large educational program is being conducted for the area residents. The lakeshore septic tank systems are being tested for efficiency. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Many research projects are underway dealing with water quality, plankton, fish, etc. Treatment results are not yet available. **REFERENCES**: Potter (pers. comm.), Seastedt and Tibbs (1972), Tibbs (pers. comm.).

LAKE NAME: Flora Lake

LOCATION: Vilas Co., Wisconsin, USA

SURFACE AREA: 41.3 ha

MAXIMUM DEPTH: 9 m

PROBLEM: Slow-growing fish species. **RESTORATION OBJECTIVE**: To increase the growth rate of largemouth bass *(Micropterus salmoides)* and panfish by removal of a part of the population. **RESTORATION METHODOLOGY**: The study was conducted 1952 through 1956. Fish were removed by netting and poisoning. The percentage weight of fish removed from the population ranged from 10.2 to 52.5%. The largemouth bass were returned except in 1954 when a toxicant was used for removal. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The growth rate of bass was unchanged but their mean weight and the yield to anglers increased 1952 to 1956. Bluegill *(Lepomis macrochirus)* growth increased as a result of thinning (the 1953 and 1954 year-classes); however, their mean weight was less in 1956. The 1954 year-class was highly successful and caused a significant increase in the catchable population in 1956. **REFERENCES**: Parker (1958).

LAKE NAME: Fork Lake

LOCATION: near Mount Zion, Illinois, USA

SURFACE AREA: 5600 m^2

MAXIMUM DEPTH: ---

PROBLEM: Poor quality sport fishery. **RESTORATION OBJECTIVE**: To eliminate the total fish population, restock with desirable species, and manage the lake for continued fish population balance. **RESTORATION METHODOLOGY**: The lake was treated with rotenone in June, 1938 and restocked with 270 stunted adult bluegills *(Lepomis macrochirus)* and 1440 largemouth bass *(Micropterus salmoides)* fry. The bluegills spawned successfully in 1938. Cropping began in 1939 using sport fishing gear and nets. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The weight removed declined steadily from 193 kg/ha in 1939 to 81 kg/ha in 1941 for bluegills and 181.5 kg/ha in 1939 to 105 kg/ha in 1941 for largemouth bass. The intensity of the removal effort increased during the period. Each successive brood of bluegills grew less rapidly. Both species reproduced successfully through 1942 (end of study). Prior to chemical treatment no macrophytes were present, apparently due to bottom rooting fish species; by 1941 dense growths of *Potamogeton foliosus* occurred in all but 2600 m^2. The ineffectiveness of cropping was thought due to the increased abundance of macrophytes. **REFERENCES**: Bennett (1949).

LAKE NAME: Fort Loudoun Reservoir

LOCATION: near Knoxville, Tennessee, USA

SURFACE AREA: ---

MAXIMUM DEPTH: 24.4 m

PROBLEM: Influx of domestic sewage after primary treatment only. **RESTORATION OBJECTIVE**: To prevent further deterioration of the water quality (in terms of public health) by providing secondary sewage treatment. **RESTORATION METHODOLOGY**: Sewage treatment plant modifications took place in 1968. This plant was the only specific source capable of significantly affecting reservoir water quality; however, some non-specific sources are also very important. The modification cost $2,609,000 USA; 20% of the average flow continued to be given primary treatment only. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Before modification the estimated BOD in the river entering the reservoir was 1.15 mg/l while afterwards it was estimated at 0.85 mg/l. The average DO near the bottom was found to be about 0.5 mg/l higher after modification but, due to colder temperatures and similar BOD's, these changes could not definitely be attributed to the modifications. Nevertheless, coliform counts decreased significantly. **REFERENCES**: Womack et al. (1973).

LAKE NAME: Fort Randall Reservoir

LOCATION: South Dakota, USA

SURFACE AREA: 477.9 km^2

MAXIMUM DEPTH: 30.5 m

PROBLEM: Nuisance population levels of carp *(Cyprinus carpio)*. **RESTORATION OBJECTIVE**: To control the carp population by drawdown immediately following periods of major spawning activity. **RESTORATION METHODOLOGY**: Predictions of the time of spawning were based on gonadal conditions of the mature fish, water temperatures, and weather forecasts. Water drawdowns of 0.46 to 0.61 m were implemented in 1955, 1956, and 1957. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In 1955 drawdowns occurred during 8–13 and 22–27 June; a small amount of earlier spawning was not affected by the drawdowns. In 1956 a drawdown occurred 12–15 June; the carp spawning period was affected. In 1957 a drawdown occurred 5–8 June; about two-thirds of the spawning was estimated to be unaffected. The young-of-the-year caught by seining each year, 1955–57, was much lower than in a nearby impoundment. The 1953 year-class dominated through the study period. Netting indicated a gradual decline in the adult carp population while other species increased. In addition to egg destruction by exposure, other control mechanisms may have been involved; although some eggs hatched, especially in 1957, the fry later disappeared. **REFERENCES**: Shields (1958).

LAKE NAME: Fox

LOCATION: Dodge Co., Wisconsin, USA

SURFACE AREA: 10.6 km^2

MAXIMUM DEPTH: 5.8 m

PROBLEM: Winterkill; turbid water; poor sport fishery; and overabundant trashfish. **RESTORATION OBJECTIVE**: To compact the bottom sediments, remove the trashfish, and restore the sport fishery. To prevent the development of winterkill conditions. **RESTORATION METHODOLOGY**: In early 1966 the water level was lowered. Toxaphene treatment occurred 21 July, 3 August, and 19 August with the lake level

1 m below normal. An attempt was made to save part of the gamefish population before treatment and the poisoned fish were removed from the lake. The piscicide was applied by helicopter. About 43 km of tributary streams were also treated. After restocking with desirable fish species only, an aeration/ circulation system consisting of eight 45 cm diameter, 2.7 m long "Helixors" was installed in the deepest area of the lake. Air was supplied via 1800 m of submerged plastic tubing at a rate of 79 cm^3/sec. Operation has occurred every winter beginning January, 1970. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: No fish were observed after the third treatment. Over 4.5×10^5 kg of fish were removed, including only 625 gamefish. In August/October after treatment, macrophytes reappeared in some areas (previously lacking) and the lake bottom could be seen at 2.1 m (0.3 m previously). About 16 ha of ice-free water existed after one month of system operation in 1970. When the system began operating dissolved oxygen levels ranged from 6–7 mg/l at the surface to 1–2 mg/l at the bottom. After about 20 days, the dissolved oxygen concentrations in the aerated basin were a uniform 3–4 mg/l. Oxygen levels in the unaerated basin of the lake reached much lower levels but were never critical. However, without the aerators, a heavy February or March snowfall may have produced winterkill conditions in the entire lake. **REFERENCES**: Kernen (1967), Wirth (1970).

LAKE NAME: Franklin Pond
LOCATION: Carter Co., Oklahoma, USA
SURFACE AREA: 8500 m^2
MAXIMUM DEPTH: --

PROBLEM: Overabundant, slow-growing fish species; poor fishing success. **RESTORATION OBJECTIVE**: To thin the overcrowded fish populations thereby increasing the growth rate of the remaining fish and improving the sport fishery. **RESTORATION METHODOLOGY**: On 16 June, 1954 the pond was partially treated with emulsified rotenone. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 90% of the fish population was eliminated. Bluegill *(Lepomis macrochirus)* and warmouth *(Chaenobryttus gulosus)* reproduced immediately following treatment; 300 fingerling largemouth bass *(Micropterus salmoides)* were stocked in November. In 1956 the fish standing crop was back near pre-treatment levels; however, there was a shift in weight composition. The warmouth increased to 135 kg/ha (3.4 kg/ha in 1954) and the bluegills decreased to 203 kg/ha (354 kg/ha in 1954). The white crappie *(Pomoxis annularis)* did not reproduce and apparently would soon disappear from the pond. Growth rates increased greatly for all species. **REFERENCES**: Jenkins (1956).

LAKE NAME: Georgetown Lake
LOCATION: Montana, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Shallow, productive lake; periodic winterkills. **RESTORATION OBJECTIVE**: To improve the winter dissolved oxygen levels in order to prevent fishkills. **RESTORATION METHODOLOGY**: An aeration system was installed consisting of a shore mounted compressor rated at 10 l/sec connected to 1200 m of perforated air line laid on the lake bottom. This system operated continuously through the late winter and early spring of 1962. During the winter of 1962–63, an identical system was installed from the opposite shore and together the two air lines crossed the entire lake. This system was operated during the winters of 1962 through 1965. A third system consisting of three small shore-mounted compressors and three separate 300 m lengths of perforated air line was also operated during the winter of 1962–1963. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The larger compressors maintained an ice-free channel about 10 m wide over the entire length of the air line, whereas the smaller compressors could open up the ice cover only during periods of mild weather. During the winter of 1962–63, when five compressors were operating simultaneously, no increase in near-surface dissolved oxygen concentrations was observed, but mid-depth and bottom dissolved oxygen concentrations remained higher than at sampling stations over 400 m away from the air lines. During the winter of 1964–65, the two larger compressors were operated late in the winter. Dissolved oxygen concentrations increased slightly in the upper waters near the air line, but no substantial improvement in dissolved oxygen concentrations was observed in the deeper parts of the lake or at distances over 90 m from the open channel. The value of the system in preventing winterkill was questionable due to a series of mild winters. **REFERENCES**: Domrose (1963), Seaburg (1966).

LAKE NAME: Giffin Pond
LOCATION: Charleston, Illinois, USA
SURFACE AREA: 4.1 ha
MAXIMUM DEPTH: 3.1 m

PROBLEM: Overabundance of leafy pondweed *(Potamogeton foliosus)* and small pondweed *(P. pusillus)*. **RESTORATION OBJECTIVE**: To control the macrophyte growths. To increase the macrophyte-free areas for bank fishermen. **RESTORATION METHODOLOGY**: Sodium endothall (37.9 l) was applied to the macrophytes in early June. Herbicides have been applied to this pond for the last six years with identical effects. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Herbicide treatment effectively eliminates the macrophytes. Regrowth does not occur due to the shading created by a subsequent algal bloom. **REFERENCES**: Hiltibran (pers. comm.), Hiltibran (1963, 1965, 1968).

LAKE NAME: Glen Lake
LOCATION: Hillsborough Co., New Hampshire, USA
SURFACE AREA: 30 ha
MAXIMUM DEPTH: 16.8 m

PROBLEM: Nuisance blue-green algal blooms (predominantly *Anabaena)*. **RESTORATION OBJECTIVE**: To control the algal growth by chemical treatment. To restore the recreational and aesthetic enjoyment of the lake. **RESTORATION METHODOLOGY**: This lake was treated with 295 kg of copper sulfate in July, 1961, in the summer of 1962, twice during the summer of 1963, and in the summer of 1970. All applications were performed by "bag dragging" to evenly distribute the copper sulfate to a 3.1 m depth. The chemical cost of one of the 1963 treatments was $86 USA. The cost of the 1970 treatment was $163. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Copper sulfate treatment provided temporary control of the algal blooms. **REFERENCES**: Frost (pers. comm.).

LAKE NAME: Goose Lake
LOCATION: Yellowstone National Park, Wyoming, USA
SURFACE AREA: 15.2 ha
MAXIMUM DEPTH: 7.6 m

PROBLEM: Undesirable population of yellow perch *(Perca flavescens)*. **RESTORATION OBJECTIVE**: To eliminate the entire fish population. **RESTORATION METHODOLOGY**: In

Sept., 1938 the lake was treated with 245 kg of derris root (5% rotenone). The piscicide was applied by surface spraying and deep water bombs. Special attention was also directed at the inflow and littoral zone. Cost of the chemical and freight charges were $192 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After eight hours great numbers of fish were dead; the average size was 10.2–12.7 cm in length. Birds and mammals ate some of the dead fish without apparent ill effect. Later sampling indicated that a complete kill had been achieved. **REFERENCES**: Barrows (1939).

LAKE NAME: Granite Basin Lake
LOCATION: Arizona, USA
SURFACE AREA: 4.5 ha
MAXIMUM DEPTH: —

PROBLEM: Overabundance of macrophytes with a summer maximum pH exceeding 10.0. **RESTORATION OBJECTIVE**: To reduce the light penetration thereby creating a light-limiting environment in order to reduce the macrophyte growth. **RESTORATION METHODOLOGY**: Nigrosine dye, at a cost of $1.00/130 kg (1945 price), was applied to the lake at a concentration of 11 kg/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The pH after initial treatment was 9.0. Another treatment at the same concentration caused the pH to drop to 7.6; it remained below that figure for the rest of the summer. Visibility dropped to 1.2 m from an original 4.9 m. Long tendrils of *Potamogeton crispus*, the dominant species in water over 2 m in depth, died and dropped to the bottom. Macrophyte growth the following spring was much inhibited with the dye still about 50% of its original strength. **REFERENCES**: Eicher (1947).

LAKE NAME: Gravel Lake
LOCATION: Rolette Co., North Dakota, USA
SURFACE AREA: 38.4 ha
MAXIMUM DEPTH: 6.7 m

PROBLEM: Shallow, eutrophic lake; periodic winterkill conditions. **RESTORATION OBJECTIVE**: To improve the winter dissolved oxygen conditions in order to prevent fishkills. **RESTORATION METHODOLOGY**: An aeration system was installed in 1962. Two air compressors supplied air to two 710 m lengths of perforated tubing placed in loops on the lake bottom in the deepest water. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Since installation of the aeration system, no fishkills have been noted. Rainbow trout *(Salmo gairdnerii)* and walleyes *(Stizostedion vitreum)* have been stocked with satisfactory results. **REFERENCES**: Kreil (1971)

LAKE NAME: Green Lake
LOCATION: near Seattle, Washington, USA
SURFACE AREA: 1 km^2
MAXIMUM DEPTH: 8.8 m

PROBLEM: Nuisance blue-green algal blooms in the summer; dense emergent vegetation problem around the shoreline; 0.3 to 1.5 m layer of easily disturbed organic sediments. **RESTORATION OBJECTIVE**: To decrease the summer standing crop of blue-green algae and to deepen the shoreline in order to reduce the macrophyte density. **RESTORATION METHODOLOGY**: In the early 1960's the lake was deepened to a limited extent by vacuum dredging. A total of about 10^6 m^3 of sediments were removed at a cost of $168,000 USA ($0.17/m^3). Starting in 1962 low-nutrient city water was added to dilute the P concentration and therefore reduce the algal population. The amount of water was determined by availability; there was much fluctuation with time, but the long term average was 1% of the lake volume/day. The capital cost was $400,000-500,000 USA and operating costs were negligible. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Measurements in 1965–67 were compared with 1959. The inflow mixed with the lake water. The concentrations in 1959 vs. 1967 were: 0.234 mg/l vs. 0.064 mg/l for total P; 0.019 mg/l vs. 0.018 mg/l for soluble P; and 0.073 mg/l vs. 0.022 mg/l for nitrate nitrogen. The concentration of total P was still higher in the lake than in the dilution water in 1967. Blue-green algal standing crops were suppressed; there was a shift in the dominant algal species (*Aphanizomenon* was eliminated); and transparency increased greatly. **REFERENCES**: Engineering News-Record (1962), Millenbach (pers. comm.), Oglesby (pers. comm.), Oglesby (1968 a and b, 1969), Oglesby and Edmondson (1966), Shepherd (1968), Sylvester (pers. comm.), Sylvester and Anderson (1960, 1964).

LAKE NAME: Lake Greenlee
LOCATION: Monroe Co., Arkansas, USA
SURFACE AREA: 1.2 km^2
MAXIMUM DEPTH: 3.7 m

PROBLEM: Overabundance of submergent macrophytes, primarily coontail *(Ceratophyllum demersum)*. **RESTORATION OBJECTIVE**: To convert the nuisance macrophytes into useful fish flesh and to provide more macrophyte-free water for sportsmen. **RESTORATION METHODOLOGY**: A herbivorous fish species, the white amur or grass carp *(Ctenopharyngodon idella)* were stocked in spring, 1970 at a rate of approximately 50.5 kg/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes disappeared and fishing improved by the winter of 1970. **REFERENCES**: Bailey (pers. comm.), Bailey (1972), Bailey and Boyd (1970).

LAKE NAME: Greenville Reservoir
LOCATION: Greenville, New Hampshire, USA
SURFACE AREA: 8 ha
MAXIMUM DEPTH: 7 m

PROBLEM: Hypolimnetic oxygen depletion; taste, odor, and color problems in the water withdrawn for municipal supplies. Near total dissolved oxygen depletion during winter ice-cover. **RESTORATION OBJECTIVE**: To oxygenate the water in the reservoir and to reduce the taste, odor and color problems. **RESTORATION METHODOLOGY**: A commercial aeration system was installed consisting of eight shore-mounted electric compressors, each delivering 2 l/sec of air to a 75 m length of perforated plastic tubing anchored on the reservoir bottom. The capital cost of the system was $8,750 USA and operating costs were about $90/month. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Operation of the system completely eliminated thermal and chemical stratification; iron and manganese concentrations were reduced by about one-tenth. Hardness, pH, nitrate nitrogen, and chloride concentrations were unaffected, but color decreased substantially. Costs of chemical treatment at the water plant were reduced by about one-third. **REFERENCES**: Rapoza, (1971).

LAKE NAME: Greenwood Lake
LOCATION: New Jersey and New York, USA
SURFACE AREA: 7.8 km^2
MAXIMUM DEPTH: 17.4 m

PROBLEM: Excessive submerged macrophytes, in particular *Potamogeton robbinsii*. Nearly 50% of the lake is infested. **RESTORATION OBJECTIVE**: To control the submergents in selected areas. **RESTORATION METHODOLOGY**: Approximately 162 ha were treated in June, 1969, and an additional 40.5 ha in June, 1970. Diquat was applied at 4.5 kg cation/ha utilizing a bottom release technique. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The 1969 treatment successfully controlled a total of approximately 190 ha. Certain other macrophyte species were also controlled. The 1970 treatment was equally effective. No regrowth has been observed since the applications. Some decrease in light penetration occurred following the 1969 treatment due to increased growth of unicellular algae. Herbicide levels were monitored for two weeks after application; no herbicide was detected after 10 days. **REFERENCES**: Gilbert (pers. comm.), Gilbert and Cortell (1970).

LAKE NAME: Lake Greenwood

LOCATION: Greenwood, South Carolina, USA

SURFACE AREA: 46.2 km^2

MAXIMUM DEPTH: 15.2 m

PROBLEM: Nutrient influx due to wastewater discharge into the tributaries. Algal blooms near the tributary inputs. **RESTORATION OBJECTIVE**: To improve the aesthetic conditions; and to preserve the lake for recreation and water supply. **RESTORATION METHODOLOGY**: The wastewaters will undergo advanced treatment. The cost is estimated at $5,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The treatment works are still in the design stage. **REFERENCES**: Abernathy (pers. comm.).

LAKE NAME: Griffin Lake

LOCATION: Lake Co., Florida, USA

SURFACE AREA: 36 km^2

MAXIMUM DEPTH: 6 m

PROBLEM: High rate of sedimentation. Flocculent sediments inhibit macrophyte growth and restrict the growth and reproductive ability of fish. **RESTORATION OBJECTIVE**: To consolidate the sediments. **RESTORATION METHODOLOGY**: Through deliberate drawdown and dam failure, the water level dropped 1.5 m in January, 1973; a large portion of the lake bottom was exposed. Drawdown of an additional 1.5 m is anticipated. The duration of the planned drawdown is not known at this time. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Preliminary data indicates that drawdown will be effective in consolidating the bottom sediments. The effect of drawdown on aquatic plants and the fishery will be monitored after refilling. **REFERENCES**: Hestand, III (pers. comm.).

LAKE NAME: Lake Hamilton

LOCATION: near Hot Springs, Arkansas, USA

SURFACE AREA: 29.2 km^2

MAXIMUM DEPTH: —

PROBLEM: Overpopulation of gizzard shad *(Dorosoma cepedianum)* and freshwater drum *(Aplodinotus grunniens)*. **RESTORATION OBJECTIVE**: To improve the sport fishery by removing the undesirable species. **RESTORATION METHODOLOGY**: In October, 1957 the water level was lowered and the lake treated with rotenone (Pro-Noxfish). The toxicant was applied by boat to provide a concentration of 0.10–0.15 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Shad were in distress within three hours. The shad population was estimated to be reduced by 90% and the drum population by 50%. About 1% by weight of the kill were gamefish. **REFERENCES**: Hulsey and Stevenson (1959).

LAKE NAME: Hamler Lake

LOCATION: Ohio, USA

SURFACE AREA: 1.4 ha

MAXIMUM DEPTH: 1.8 m

PROBLEM: Unbalanced fish population dominated by small panfish; poor quality sport fishery. **RESTORATION OBJECTIVE**: To eliminate the fish population and restock with a bass *(Micropterus salmoides)*—bluegill *(Lepomis macrochirus)* combination. To prevent bluegill overabundance by periodically supplementing the bass population and by partial poisoning. **RESTORATION METHODOLOGY**: Rotenone was applied on 19 Sept., 1949 at a concentration of 2 mg/l. In spring, 1950, the lake was restocked with 400 fingerling bluegills and 400 yearling bass. Additional bass were stocked in fall, 1950 (3069 fingerlings); in fall, 1951 (1000 fingerlings); in fall, 1952 (1200, 10–20 cm in length); and in fall, 1953 (2762, 10–20 cm in length). In 1954 partial poisoning was conducted within a 3.7 m wide band around the shoreline. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After treatment in 1949, fish were removed for three days, a total of 72 kg/ha. The population was composed of 62% desirable species but of an undesirable size. Following restocking, there were indications of a rapidly developing overabundant, slow-growing bluegill population by 1951. The supplemental bass stocking had no apparent effect on the bluegill population. Partial poisoning resulted in improved bass production but no increase in the number of desirable-sized bluegills. **REFERENCES**: Clark (1964).

LAKE NAME: Ham's Lake

LOCATION: W. Stillwater, Oklahoma, USA

SURFACE AREA: 40 ha

MAXIMUM DEPTH: 8 m

PROBLEM: Heavy organic waste loadings from catfish (*Ictalurus* sp.) operations; hypolimnetic oxygen depletion during periods of thermal stratification. **RESTORATION OBJECTIVE**: To maintain adequate dissolved oxygen levels in the bottom waters. **RESTORATION METHODOLOGY**: A water pump was developed to transfer about 630 l/sec from the 1.2 m level to the lake bottom. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Prior to operation a top to bottom temperature differential of 6.5° C existed and dissolved oxygen was absent in the bottom 3 m. After six weeks of pumping, the temperature differential was reduced to 1° C, and 2 mg/l of dissolved oxygen was present in the bottom waters. **REFERENCES**: Garton (pers. comm.; a report is in preparation).

LAKE NAME: Harriet

LOCATION: Minneapolis, Minnesota, USA

SURFACE AREA: 1.4 km^2

MAXIMUM DEPTH: 27.4 m

PROBLEM: Nutrient enrichment via urban storm runoff. High populations of blue-green algae. **RESTORATION OBJECTIVE**: To reduce the nutrient influx and/or shift the algal dominance from blue-greens to greens. **RESTORATION METHODOLOGY**: Two storm water drainage areas were chosen for study. In one case nearly 100% of the residents agreed to use a phosphate-free fertilizer on their lawns and gardens (the majority of the residents were fertilizer users); the frequency of street sweeping was increased in both drainage areas. The effect of these treatments upon the water quality of the storm runoff was measured in 1972. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not now available. **REFERENCES**: Lundquist (pers. comm.; a report is in preparation).

LAKE NAME: Hemlock Lake
LOCATION: Cheboygan Co., Michigan, USA
SURFACE AREA: 1.8 ha
MAXIMUM DEPTH: 18.6 m

PROBLEM: Hypolimnetic oxygen depletion; phosphorus regeneration from sediments. **RESTORATION OBJECTIVE**: To maintain oxidizing conditions in the sediments and the overlying waters. To study the effects of hypolimnetic aeration on sediment nutrient release and the biota. **RESTORATION METHODOLOGY**: The equipment was designed to aerate the hypolimnion without disrupting the lake's thermal stratification. Air was introduced through a diffuser at the base of a 1.38 m diameter pipe which extended from the lake's surface to a depth of 15.5 m. A second tube, 12.3 m in length and 1.85 m in diameter, was placed concentrically around the smaller tube and extended 3.1 m above the lake surface. Water was airlifted up the inner tube and returned to the hypolimnion through the annular space. Air was supplied at a rate of 62 l/sec during June–July, 1970; 47 l/sec during July–September, 1970; and 24 l/sec during a 48 hr period in January, 1971. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Within nine days the hypolimnetic oxygen levels increased from zero to 8 mg/l. During operation of the system there also was an increase in pH and a decrease in carbon dioxide, total alkalinity, and conductivity in the hypolimnion. Due to leaks in the system and heat transfer through the pipe walls, the bottom water temperature increased gradually. Intense algal blooms occurred immediately after the onset of aeration and in August; production and standing crops were unusually low during the intervening period. Zooplankton and zoobenthos populations increased during aeration, primarily due to the enlarged livable zone. Although the system was not as successful as anticipated, the difficulties were thought due to improper design of the equipment. In the winter of 1970–71, dissolved oxygen concentrations were much higher than during the previous winter, presumably due to increased decomposition of organic material during the summer. A short test of the aerator succeeded in increasing the oxygen levels. **REFERENCES**: Ball (pers. comm.), Fast (1971a, 1973).

LAKE NAME: Herman Lake
LOCATION: Madison, South Dakota, USA
SURFACE AREA: 5.3 km^2
MAXIMUM DEPTH: 3 m

PROBLEM: Sediment accumulation. Decreased water depth; occasional winterkills. **RESTORATION OBJECTIVE**: To deepen part of the lake in order to provide a sufficient volume of oxygenated water for overwinter fish survival. **RESTORATION METHODOLOGY**: A 4 ha bay was deepened to an average depth of 3.5 m with a 25 cm hydraulic cutterhead dredge. About 54,000 m^3 of sediments were removed at a cost of $0.25 USA/m^3. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Dredging was recently completed, and results with respect to winterkill are not yet available. Water quality was carefully monitored during the dredging and there apparently was little effect. Based on background data and simultaneous monitoring in a downstream lake, the only water quality parameter that may have been affected by dredging was orthophosphate. Concentrations approximately doubled throughout the lake; however, no concentration gradient was detected towards the dredged area. Turbidity created by the dredge was less than that which developed in the water during high winds. **REFERENCES**: Brashier (pers. comm.), Brashier et al. (1973), Johnson (pers. comm.).

LAKE NAME: Heyburn Lake
LOCATION: southwest of Tulsa, Oklahoma, USA
SURFACE AREA: 4 km^2
MAXIMUM DEPTH: --

PROBLEM: Excessive turbidity; unaesthetic and unsafe for swimming. Water clarity near 15 cm and turbidity between 170 and 220 JTU. **RESTORATION OBJECTIVE**: To clarify a 4 ha bay of the reservoir using Purifloc C-31. To enhance the recreational value of a portion of the lake. **RESTORATION METHODOLOGY**: Purifloc C-31 was applied on 3 and 7 October, 1969 by surface spraying (shallow areas) and underwater injection. Laboratory tests indicated that the dosage rate of 5 mg/l would reduce the turbidity to 20 JTU. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Floc formation was observed within 10 minutes and the water clarified noticeably within two hours. High winds, however, limited the amount of floc that settled to the bottom. The best results occurred in the relatively protected areas. In these areas initially the turbidity dropped to 10 JTU or less; nevertheless, the turbidity was again increasing by the end of the study periods (24–30 hrs after each treatment). Better results require some type of barrier across the mouth of a protected cove. **REFERENCES**: Goddard and Schaefer (undated).

LAKE NAME: Hills Creek Reservoir
LOCATION: Lane Co., Oregon, USA
SURFACE AREA: 11 km^2
MAXIMUM DEPTH: 75 to 94 m

PROBLEM: High turbidity. There are biological, aesthetic, and economic problems arising from the effect of reservoir turbidity of fish and wildlife, recreation, and other uses. **RESTORATION OBJECTIVE**: To determine the cause and source of the turbidity. To control the turbidity via modifications in reservoir operation and management and drainage basin land use practices. **RESTORATION METHODOLOGY**: Restoration has not yet been attempted, but the following methods are being considered: (1) close management of all drainage basin activities to minimize soil distrubance, especially in relation to road construction. Logging methods that minimize the amount of roads should be used in unstable soil areas and perhaps no logging at all in some places, (2) lower water levels to reduce bank erosion and shoreline riprapping (this is a minor source of the turbidity), (3) maximum drawdown during the winter to remove the silt laden waters before refilling, and (4) selective withdrawal of the especially turbid layers during the winter. The last two alternatives are aimed primarily at improving the quality of the discharge rather than in-lake conditions. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A variety of physico-chemical and biological parameters have been investigated and are available for comparison with post-restoration conditions (the lake can be classified as oligotrophic). **REFERENCES**: Larson (pers. comm.), Pope (pers. comm.), Youngberg et al. (1971).

LAKE NAME: Lake Hiwassee
LOCATION: Oklahoma Co., Oklahoma, USA
SURFACE AREA: 62.4 ha
MAXIMUM DEPTH: --

PROBLEM: Overpopulation of slow-growing fish, especially white crappie *(Pomoxis annularis)* and bluegill *(Lepomis macrochirus)*; poor sport fishing. **RESTORATION OBJECTIVE**: To improve the fish population characteristics by partial removal. **RESTORATION METHODOLOGY**:

Powdered derris root (5% rotenone) was applied once annually for four years–April, 1951; May, 1952; June, 1953; and June, 1954. In 1951, 8.1 ha were treated by boat and hand spraying (227 kg were applied). In 1952, 12.2 ha were treated in the same manner with a similar amount. In 1953 and 1954, 454 kg were sprayed along the shoreline. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: By 1954 the large population of gizzard shad *(Dorosoma cepedianum)* was nearly eliminated; the carp *(Cyprinus carpio)* population responded to reduction with increased reproduction. The rate of growth increased for largemouth bass *(Micropterus salmoides)*, redear sunfish *(Lepomis microlophus)*, and bluegill but the overall effect on growth and fishing success was unsatisfactory. The total amount of toxicant used would have been enough to completely eliminate the population in a single treatment. **REFERENCES**: King (1953, 1954).

LAKE NAME: Hodges Reservoir

LOCATION: near San Diego, California, USA

SURFACE AREA: 72.5 ha

MAXIMUM DEPTH: 15.3 m

PROBLEM: Very high plankton counts and excessive turbidity. **RESTORATION OBJECTIVE**: To increase the water clarity through removal of the carp *(Cyprinus carpio)* population. **RESTORATION METHODOLOGY**: The reservoir was treated with rotenone in January, 1956. Emulsified rotenone (Pro-Noxfish) was applied by boat to achieve an average concentration of 1.8 mg/l. The concentration in the deepest part of the lake was 0.75 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Fish began dying within 1/2 hour. A total of 99,000 kg were removed of which 97,000 kg were carp. Surface plankton counts decreased markedly except for Protozoa; and water clarity increased immediately after treatment. Plankton recovered quickly, however. **REFERENCES**: Hoffman and Payette (1956).

LAKE NAME: Lake Hollingsworth

LOCATION: Lakeland, Florida, USA

SURFACE AREA: 1.5 km^2

MAXIMUM DEPTH: —

PROBLEM: Overabundant trashfish; nonexistent fishery due to few sport fish and little to no reproduction. **RESTORATION OBJECTIVE**: To improve the sport fishery by reducing the trashfish population. **RESTORATION METHODOLOGY**: In 1949, 52 kg/ha of trashfish were removed by seining. Continued removals equalled 133 and 210 kg/ha in 1950 and 1951, respectively. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Before removal in 1949 the adult population was composed of only 0.3% game and panfish; 99.7% were trashfish species (98% shad, *Dorosoma* sp.). In 1950 the desirable species increased to 3.4% of the total. The panfish fishing was greatly improved in 1951 (based on observation) and the percentage of desirable species was 12.2 of the total. Reproduction was noted for most species. **REFERENCES**: Dequine (1952).

LAKE NAME: Hooker Lake

LOCATION: Rolette Co., North Dakota, USA

SURFACE AREA: 14 ha

MAXIMUM DEPTH: 7.6 m

PROBLEM: Eutrophic; periodic occurrence of winterkill conditions. Hypolimnetic oxygen depletions restrict fish habitat during the summer. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen levels during both summer and winter. **RESTORATION METHODOLOGY**: An aeration system was installed in August, 1966. Initially only one small compressor was used, but the system was enlarged in early summer, 1967. The system was operated year-round until April, 1969. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Operation of the enlarged system maintained partial destratification during the summers of 1967 and 1968. The maximum top to bottom temperature differential noted was about 7°C. Anaerobic conditions existed in the bottom waters on several occasions during the summers and surface water dissolved oxygen concentrations as low as 1.2 mg/l were also noted. No winterkills occurred during the period of aeration, although the role of the aeration system in preventing winterkill was not clear due to climatic factors. **REFERENCES**: Kreil (1971).

LAKE NAME: Horseshoe

LOCATION: Manitowoc Co., Wisconsin, USA

SURFACE AREA: 9 ha

MAXIMUM DEPTH: 17 m

PROBLEM: Nuisance blue-green algal blooms and winter fishkills. Eutrophic conditions apparently induced by agricultural wastes and the prior influx of dairy wastewaters. **RESTORATION OBJECTIVE**: To limit planktonic algal growth and improve dissolved oxygen conditions by reducing the phosphorus concentration. **RESTORATION METHODOLOGY**: Precipitation/sorption and settling of phosphorus was attempted in May, 1970. Slurried alum was applied at a rate of 10 mg of aluminum/l in the surface 0.6 m. The chemical costs were $74 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment decreased the total phosphorus in the lake water. Concentrations of phosphorus were reduced for two years (period of study) after treatment. Of particular significance, the phosphorus concentrations in the hypolimnion were diminished and maintained at low levels. Although *Chara* became more abundant, nuisance planktonic algal blooms were eliminated. Dissolved oxygen concentrations in the hypolimnion were increased. No adverse ecological consequences were observed. **REFERENCES**: Peterson et al. (1973).

LAKE NAME: Hyrum Reservoir

LOCATION: Hyrum, Utah, USA

SURFACE AREA: 1.9 km^2

MAXIMUM DEPTH: 27 m

PROBLEM: Nuisance blooms of blue-green algae *(Aphanizomenon flos-aquae)*. **RESTORATION OBJECTIVE**: To eliminate the algal blooms. **RESTORATION METHODOLOGY**: Artificial circulation of the reservoir is planned to begin June, 1973. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The project is still in a pre-treatment stage. **REFERENCES**: Porcella, Gearheart, and Drury (pers. comm.).

LAKE NAME: Indian Lake

LOCATION: near Worcester, Massachusetts, USA

SURFACE AREA: 69.7 ha

MAXIMUM DEPTH: 4.6 m

PROBLEM: Poor quality sport fishery. **RESTORATION OBJECTIVE**: To improve the fishery by selective removal of overabundant panfish and trashfish. **RESTORATION METHODOLOGY**: Intensive thinning operations were carried out in 1954, 1955, and 1956 using fyke nets. Removal amounted to 87.5, 18.5, and 16.2 kg/ha for these respective years. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In

1955 about 75% by number were white perch *(Morone americana)*, they averaged 15.2 cm with a mean age of 5 yrs. By 1956 only 55% were white perch and they averaged almost 20.3 cm with a mean age of less than 3 yrs. The ratio of gamefish to other species remained the same during the study period. Although not as marked, the growth rates of yellow perch *(Perca flavescens)* and black crappie *(Pomoxis nigromaculatus)* also increased. The growth rate of largemouth bass *(Micropterus salmoides)* and chain pickerel *(Esox niger)* decreased slightly from 1954 to 1956. **REFERENCES**: Grice (1958).

LAKE NAME: Indian Brook Reservoir
LOCATION: Ossining, New York, USA
SURFACE AREA: 7.3 ha
MAXIMUM DEPTH: 8.4 m

PROBLEM: Low alkalinity, 14–18 mg/l. Used as a water supply for a municipal filtration plant and the alkalinity even after lime addition is insufficient to control corrosion. **RESTORATION OBJECTIVE**: To increase the alkalinity in order to permit adequate treatment and corrosion control. **RESTORATION METHODOLOGY**: Various methods for increasing the bicarbonate alkalinity were tried with limited success, including the spreading of lime on the ice during the winter. In 1956 an aeration/circulation system was installed. Air was introduced about 2.2 m below the water surface at a rate of 75 l/sec. Milk of lime was added at a rate of 1.0 l/sec through a spray pipe at the surface above the aerator. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The system ran continuously from July, 1956 to January, 1957; stratification was completely eliminated after one week. Dissolved oxygen concentrations and temperatures in the hypolimnion increased to approximately the same values as the surface without substantial change in the surface conditions. Iron concentrations in the bottom waters decreased from 1.5–2.0 mg/l to 0.1–0.2 mg/l and carbon dioxide concentrations decreased from 10–20 mg/l to 1–3 mg/l. Color was reduced, bicarbonate alkalinity increased to 35 mg/l, and the pH leveled off in the range of 6.8 to 7.3. Algae showed a decrease of 60–80%, whereas benthic crustacea increased about four times. **REFERENCES**: Riddick (1957).

LAKE NAME: Indian Creek Reservoir
LOCATION: Alpine Co., California, USA
SURFACE AREA: 65 ha
MAXIMUM DEPTH: 17 m (full pool)

PROBLEM: Fishkill during the winter of 1968–69. Constructed in 1968, this reservoir receives the sewage treatment plant effluent from the Lake Tahoe Basin. **RESTORATION OBJECTIVE**: To prevent future fishkills. **RESTORATION METHODOLOGY**: In January, 1970 an aeration/circulation system was installed, consisting of 10 76 m lengths of weighted perforated tubing placed in the deepest portion of the reservoir. Each section of perforated tubing was connected to a compressor mounted on the dam. The aerators were started up in early January, 1970 but due to vandalism, operation was discontinued in February. Aeration was started again in March, but discontinued after 10 days of operation. In late June, the aerators began to run more or less continuously. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Before and after aeration, periods of both complete mixing and strong stratification occurred in the reservoir, and the effect of aeration was uncertain. No winterkill of fish occurred during the winters of 1969–1970 or 1970–1971 when the aerators were operating, but it was not clearly demonstrated that the previous fishkill was in fact due to low dissolved oxygen conditions. **REFERENCES**: Boulier (1971). Lake Tahoe Area Council (1971).

LAKE NAME: Indiana Univ. Reservoir
LOCATION: Indiana, USA
SURFACE AREA: –
MAXIMUM DEPTH: –

PROBLEM: Hypolimnetic oxygen depletion; taste and odor problems during late summer. Used as a water supply reservoir. **RESTORATION OBJECTIVE**: To eliminate the anoxic conditions in the hypolimnion. **RESTORATION METHODOLOGY**: An aeration system was installed in the summer of 1919. Air was released near the bottom of the reservoir from three 2.1 m lengths of perforated pipe connected to a shore-based compressor. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The quality of the water improved markedly. The rising bubbles set up a current which mixed the anoxic bottom waters with the surface waters. Temperature and dissolved oxygen became nearly uniform from the 8 m level to the surface. **REFERENCES**: Scott and Foley (1919).

LAKE NAME: J. Percy Priest
LOCATION: Davidson-Rutherford Co., Tennessee, USA
SURFACE AREA: 57 km2
MAXIMUM DEPTH: 30 m

PROBLEM: Potential eutrophication due to nutrient input from treated sewage as well as urban and agricultural runoff. **RESTORATION OBJECTIVE**: To prevent or delay problems associated with advanced eutrophication. **RESTORATION METHODOLOGY**: Various techniques are under consideration; a cooperative study is presently underway to develop a basis for recommendations. This should be completed in 1974. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Pretreatment investigations are continuing. The study includes identification and quantification of nutrient sources and their relationship to and effect on reservoir water quality. **REFERENCES**: Sansing (pers. comm.).

LAKE NAME: Jacobs Pond
LOCATION: Plymouth Co., Massachusetts, USA
SURFACE AREA: 18.2 ha
MAXIMUM DEPTH: 1.2 m

PROBLEM: Overabundance of macrophytes, probably due to shallow water rather than excess nutrients. **RESTORATION OBJECTIVE**: To remove the macrophytes thereby allowing increased recreational usage of the area. **RESTORATION METHODOLOGY**: Two methods are under consideration: (1) macrophyte harvesting at a probable cost of $370 USA/ha, and (2) drainage and dredging at a cost of $1.31/m^3 of material removed. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: One of the techniques will probably be implemented in the spring of 1973. **REFERENCES**: Magazu (pers. comm.).

LAKE NAME: Jennings
LOCATION: Lakeside, California, USA
SURFACE AREA: 72 ha
MAXIMUM DEPTH: 42 m (full pool)

PROBLEM: Hypolimnetic oxygen depletion; taste, odor, and color problems in water withdrawn for municipal supplies. **RESTORATION OBJECTIVE**: To maintain high quality water throughout the entire depth of the reservoir throughout the year. **RESTORATION METHODOLOGY**: A total aeration system was installed to increase the oxygen content of the bottom water. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Satisfactory dissolved oxygen levels have been maintained at all depths since start-up, with the resultant reduction in taste, odor, and color problems. Salmonid populations are now able to survive in the deeper parts of the lake during the summer. **REFERENCES**: Flor (pers. comm.).

LAKE NAME: Jordan Pond
LOCATION: near Shrewsbury, Massachusetts, USA
SURFACE AREA: 8.1 ha
MAXIMUM DEPTH: 4.3 m

PROBLEM: Poor quality sport fishery. **RESTORATION OBJECTIVE**: To improve the gamefish population by selectively removing the overabundant panfish and trashfish. **RESTORATION METHODOLOGY**: Intensive thinning operations were carried out in 1953, 1954, and 1955 using fyke nets. Removal amounted to 118, 103 and 44 kg/ha for these respective years. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The catch consisted of 40% (by weight) bluegills *(Lepomis macrochirus)* in 1953 and 1954 and 65% in 1955. Increased growth rates resulted for bluegill, white perch *(Morone americana)*, and yellow perch *(Perca flavescens)*. **REFERENCES**: Grice (1958).

LAKE NAME: Jyme
LOCATION: Oneida Co., Wisconsin, USA
SURFACE AREA: 4000 m^2
MAXIMUM DEPTH: 3.6 m

PROBLEM: Accumulation of low density, organic-rich sediments (6 m thick). **RESTORATION OBJECTIVE**: To determine the effectiveness of drawdown and sediment drying as a technique for consolidating the sediments in a natural lake. **RESTORATION METHODOLOGY**: A high capacity irrigation pump was used to remove the lake water to a nearby marsh. The water level in the lake was lowered at about 15 cm/hr. The inflow of low density sediments from beneath a floating bog adjacent to the lake forced the termination of pumping prior to complete drawdown. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Although laboratory testing indicated that the sediments were highly susceptible to consolidations, valid in-lake data were not obtained because of sediment flow and incomplete drawdown. The low strength characteristics of the upper layers of the sediments permitted movement as the lake level was lowered. Measurable consolidation did, however, occur in the stable portions of the adjacent bog at distances up to 30 m from the lake. Extensive slumping also occurred in the bog during lake drawdown, but most evidence of slumping disappeared as the lake refilled. **REFERENCES**: Smith et al. (1972).

LAKE NAME: Kegonsa
LOCATION: Dane Co., Wisconsin, USA
SURFACE AREA: 11 km^2
MAXIMUM DEPTH: 9.5 m

PROBLEM: Overabundant trashfish population. **RESTORATION OBJECTIVE**: To determine the effect of trashfish removal on the remaining population (trashfish and other species). **RESTORATION METHODOLOGY**: During 1937–51 trashfish were removed by netting. A total of 401 seine hauls were made, removing 4,191,815 kg at a catch rate of 10,450 kg/unit effort. The trashfish were comprised primarily of carp, *Cyprinus carpio* (98% of the total catch). The weight of carp removed ranged from 77.5 to 459 kg/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The catch rate varied from year to year but was above the mean before the mid-1940's and lower afterwards. Individual year-classes of carp strongly influenced the catch rate; the rate was increasing sharply at the end of the study. The sheepshead *(Aplodinotus grunniens)* catch rate was above the overall average after 1943 (one exception) and was increasing at the end of the study. The gar *(Lepisosteus* sp.) catch rate exhibited great variation during the study period, but was near zero in 1951. Gamefish were not captured in great numbers during the seining; however, analysis of population trends were conducted for some of the prevalent species. The catch rate of crappie *(Pomoxis* sp.) and perch *(Perca flavescens)* showed an overall decline despite major fluctuations during the period of study. The other species fluctuated greatly and no trends were evident. **REFERENCES**: Hacker (1952).

LAKE NAME: Kegonsa
LOCATION: near Madison, Wisconsin, USA
SURFACE AREA: 11 km^2
MAXIMUM DEPTH: 9.5 m

PROBLEM: Advancing eutrophication. Nuisance blue-green algal blooms were occurring in an upstream lake due to the influx of sewage treatment plant effluent. **RESTORATION OBJECTIVE**: To divert the sewage effluent out of the drainage basin. **RESTORATION METHODOLOGY**: The construction of an open channel was completed in 1958. The treated sewage was transported 6.1 km to a small creek outside of the drainage basin at a cost of $3,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The treated sewage had contributed 75 and 86% of the inorganic nitrogen and soluble phosphorus inflow, respectively, to the upstream lake (Waubesa). In Kegonsa in the summer of 1959 there was no reduction in the concentrations of nitrogen or phosphorus. Three winters after diversion the soluble phosphorus concentrations were decreased by approximately 30%. The hydraulic residence time was 5.2 months. One year after diversion a diverse algal population still existed and the blue-green algae did not produce nuisance conditions. **REFERENCES**: Fitzgerald (1964, 1965), Lawton (1961), Sonzogni and Lee (1972).

LAKE NAME: Kezar Lake
LOCATION: North Sutton, New Hampshire, USA
SURFACE AREA: 73 ha
MAXIMUM DEPTH: 8.2 m

PROBLEM: Nuisance blooms of blue-green algae, primarily *Aphanizomenon*. Cell counts exceed 10^6/ml at 0.5 m and water clarity was less than 0.3 m. **RESTORATION OBJECTIVE**: To improve the water clarity by controlling the blue-green algal blooms. To increase the recreational potential of the lake and the shoreline property values. **RESTORATION METHODOLOGY**: Destratification was accomplished during 1968 and 1969 by releasing compressed air from 12 ceramic diffusers placed in the deepest part of the lake. Plastic tubing connected the diffusers to four shore-based air compressors powered by electric motors. The system operated continuously during the summers. Rental costs for the aeration system were about $2800 USA/yr. Electrical power costs were about $500/4 mos. Nutrient stripping facilities are now under construction at the existing sewage treatment plant. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Complete destratification occurred during 1968, but due to mechanical problems, complete mixing never took place during 1969.

Secchi disc readings gradually increased to 1.5 m by October, 1968 (0.3 m one week before operation in July). During 1969, the minimum Secchi disc reading was 0.6 m and generally averaged greater than 1 m. Destratification distributed the algae throughout the water column in 1968 and after two weeks of operation the standing crop of *Aphanizomenon* was greater than before aeration. After three weeks, the predominance of *Aphanizomenon* began to decline, but a heterogenous algal community with a high standing crop prevailed until the end of the summer. In 1969 aeration was initiated near the end of May, about seven weeks earlier than in 1968, but the cell counts of *Aphanizomenon* still reached the 1968 levels by late June. By mid-July an intense bloom of green algae occurred which lasted until September. **REFERENCES**: Frost (pers. comm.), Haynes (pers. comm.), Haynes (1971, and in press), New Hampshire Water Supply and Pollution Control Commission (1971), Turner et al. (1972).

LAKE NAME: Koshkonong

LOCATION: Jefferson, Dane, and Rock Cos., Wisconsin, USA

SURFACE AREA: 40.1 km^2

MAXIMUM DEPTH: 2.1 m

PROBLEM: Overabundant trashfish population, esp. carp *(Cyprinus carpio)*. **RESTORATION OBJECTIVE**: To control the carp population by continued mechanical removal thus benefiting the gamefish and improving the sport fishery. **RESTORATION METHODOLOGY**: Carp removal by seining began in 1934; earlier removal operations had also been conducted but at a low level and records of the catch were not maintained. From 1934 to 1952 the annual catch ranged between 1.78 x 10^5 and 8.93 x 10^5 kg. The seine was 1525–1830 m in length and enclosed more than 36.5–52.7 ha. The number of seine hauls varied from 34 to 198/yr. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Catch per unit of effort data indicated that carp populations were reduced by removal, but due to uncontrolled reproduction, periodically the population increased to pre-removal levels. Wide fluctuations were evident in the abundance of gamefish populations. In general the gamefish population increased greatly in the late 1930's, remained high for several years, and then dropped to approximately pre-removal levels. The changes in gamefish populations were not clearly related to carp abundance. Winterkill was thought to be a dominant influence. **REFERENCES**: Threinen (1952).

LAKE NAME: Krause Springs

LOCATION: Langlade Co., Wisconsin, USA

SURFACE AREA: 4000 m^2

MAXIMUM DEPTH: 1 m (before deepening)

PROBLEM: Restricted sport fishery due to an accumulation of sediments. **RESTORATION OBJECTIVE**: To deepen the pond in order to increase the fish habitat. **RESTORATION METHODOLOGY**: A hydraulic cutterhead dredge was used to deepen the pond to a maximum depth of 3.7 m. About 4,500 m^3 of sediments were removed at a total cost of $8,720 USA ($1.93/m^3). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The number of age 0 trout *(Salvelinus fontinalis)* increased by more than 50% after dredging. The dredge removed over 95% of the benthic invertebrates, but the benthos biomass increased to about 50% of pre-dredging levels after 18 months. Chironomidae accounted for most of the recolonization; Amphipoda and Hirundinea showed little increase. During the second year after dredging, planktonic crustacea became abundant, particularly *Daphnia ambigua*. Prior to dredging no *Daphnia* were collected. The effects of dredging are still being studied. **REFERENCES**: Carline (pers. comm.).

LAKE NAME: Ladora

LOCATION: Aurora, Colorado, USA

SURFACE AREA: 25 ha

MAXIMUM DEPTH: —

PROBLEM: Contaminated with aldrin and dieldrin pesticides in the early 1950's, about 3,000 ducks died annually. The lake was completely unsuitable for fishing. **RESTORATION OBJECTIVE**: To remove the contaminated bottom sediments. **RESTORATION METHODOLOGY**: During a four-year period in the early 1960's approximately 15 cm of the uppermost lake sediments were removed. The inlet channel was also modified after a duck mortality in 1966. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Several fish species stocked in late 1968 exhibited good growth and survival. However, pesticide analyses in 1970 showed from 3 to 4 mg/l dieldrin present in the fish flesh. No chlorinated hydrocarbons were present in the lake water at detectable levels, but aquatic vegetation was apparently concentrating the contaminant. **REFERENCES**: Mullan (1970).

LAKE NAME: Lafayette Reservoir

LOCATION: Contra Costa Co., California, USA

SURFACE AREA: 53 ha

MAXIMUM DEPTH: 24 m

PROBLEM: Nuisance algal blooms; taste and odor problems. Used for recreation and as a municipal water supply reservoir. **RESTORATION OBJECTIVE**: To eliminate the anaerobic conditions in the bottom waters and to control the algal blooms. **RESTORATION METHODOLOGY**: An aeration system, consisting of 100 m of perforated plastic tubing with 0.8 mm holes at 15–30 cm intervals, was installed near the dam at the 18 m depth. Each end of the perforated tube was connected to a gasoline-powered compressor mounted on the dam and rated at 28 l/sec, 3.5 kg/cm^2. The cost of the system was $7000 USA. Aeration began in 1967 and has continued to the present on an 8-hour/day, 5 days/week basis. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: System operation nearly eliminated the normal 11° C top to bottom summer water temperature differential. The maximum surface temperature during the first year was about 1–3° C below the long-term average maximum and evaporation losses were reduced by 12%. Surface DO levels were unaffected, but bottom concentrations were increased to within 7% of those near the surface. Objectionable tastes and odors were eliminated from the bottom waters. Turbidity was unchanged, but algal biomass increased and blue-greens remained dominant. There was an apparent increase in fish growth rates and spawning has reportedly been enhanced. **REFERENCES**: Knutson (pers. comm.), Laverty and Nielson (1970).

LAKE NAME: Lafourche Lake

LOCATION: northeastern Louisiana, USA

SURFACE AREA: 4.1 km^2

MAXIMUM DEPTH: 4–6 m

PROBLEM: Noxious macrophyte growths and undesirable fish population characteristics. **RESTORATION OBJECTIVE**: To determine the effect of water level fluctuation (drawdown) on limnological conditions. **RESTORATION METHODOLOGY**: Three drawdowns were implemented: (1) 1.2 m in the winter of 1961–62, (2) 3.4 m during 1962, starting 5 July, and (3) during the summer of 1963. **RESULTS (OR STATUS FOR

ONGOING PROJECTS): Following the first drawdown the weight of desirable-sized predatory and non-predatory gamefish species increased greatly; this initial increase disappeared by 1964. The sport fish harvest was about 27 kg/ha (0.3 kg/hr) in 1962–63 (no pre-treatment data available) and did not increase the next fishing season. By 1964 the macrophytes were reduced by about 50%. **REFERENCES**: Davis and Hughes (1964), Lantz et al. (1964).

LAKE NAME: Lake of the 4 Seasons
LOCATION: Crown Point, Indiana, USA
SURFACE AREA: 1.2 km^2
MAXIMUM DEPTH: 9.2 m

PROBLEM: Excessive algae and macrophytes; high nutrient content; high water temperature; and fecal contamination. **RESTORATION OBJECTIVE**: To improve the recreational potential (e.g., swimming, fishing, water skiing) of the area. **RESTORATION METHODOLOGY**: The lake was treated with cutrine at 2 mg/l to reduce the blue-green algal blooms. After treatment with cutrine, alum was applied at the rate of 224.2 kg/ha to tie up the phosphorus. Dilutional pumping from three wells (4750 m^3/day) was also employed. The costs were estimated at $5,000 USA/yr. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After treatment with cutrine the blue-green algal count dropped from 6.5 x 10^6/l to zero and after the alum treatment, the orthophosphate was reduced from 2 mg/l to 0.2 mg/l. The nutrient and floral levels gradually stabilized; algal blooms did not recur. **REFERENCES**: Dustman (pers. comm.).

LAKE NAME: Lake of the Arbuckles
LOCATION: Sulphur, Oklahoma, USA
SURFACE AREA: 22.3 km^2
MAXIMUM DEPTH: 37 m

PROBLEM: Low dissolved oxygen content and poor water quality. Used as a municipal water supply. **RESTORATION OBJECTIVE**: To increase the DO levels in the hypolimnion. **RESTORATION METHODOLOGY**: The lake will be destratified using a modified hydraulic gun. Other aeration/circulation devices may also be tested. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The equipment is under construction and limnological data collection activities are underway. **REFERENCES**: King (pers. comm.).

LAKE NAME: Larson Lake
LOCATION: Lincoln Co., Wisconsin, USA
SURFACE AREA: 4.5 ha
MAXIMUM DEPTH: 12 m

PROBLEM: Hypolimnetic oxygen depletion; development of winterkill conditions. **RESTORATION OBJECTIVE**: To maintain adequate dissolved oxygen levels in the bottom waters without disrupting thermal stratification during the summer. To prevent winterkill without creating open water areas. To develop techniques for use elsewhere. **RESTORATION METHODOLOGY**: A hypolimnetic aerator was installed through the ice in early February, 1973. The aerator consisted of an 11-m long "Helixor"; water airlifted up the "Helixor" entered a separation box at the surface, where bubbles were vented to the atmosphere, and returned to the hypolimnion via two flexible return tubes. Air was supplied from an on-shore compressor at about 7 l/sec with a pressure of 0.12 kg/cm^2. Capital cost of the aerator was about $3,000 USA and operating costs were approximately $60/month. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After six weeks of full-time operation, the minimum dissolved oxygen concentration recorded in the lake was 6 mg/l (originally zero near the bottom). At no time did the aerator create any open water and the separation box at the top of the "Helixor" remained frozen in the ice. The aerator was restarted in the first part of May, 1973 when the lake was beginning to stratify, with the compressor running at about half-speed. Preliminary results indicate that the aerator can effectively maintain 7 mg/l of dissolved oxygen in the normally anoxic hypolimnion without disrupting thermal stratification. **REFERENCES**: Smith (pers. comm.).

LAKE NAME: Lion's Lake
LOCATION: Johnson Co., Missouri, USA
SURFACE AREA: 2.4 ha
MAXIMUM DEPTH: 5 m (after deepening)

PROBLEM: Excessive sediment accumulation. Water volume reduced to about 25% of the original capacity. Overabundant macrophytes and nuisance algal growths in the shallow areas. **RESTORATION OBJECTIVE**: To deepen the lake in order to restore its lost capacity. To alleviate the flora-related problems. **RESTORATION METHODOLOGY**: After drainage and sediment desiccation, the lake was deepened about 1.5 m over most of the bottom. Approximately 61,000 m^3 of sediment were removed over a six-year period at a cost of $10,000 USA ($0.16/m^3). The lake was refilled in 1970. To reduce future siltation, some modifications were made in the upstream areas. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The overall recreational value of the pond has been substantially increased, with deeper water, correction of the vegetation problem, and good fishing. **REFERENCES**: Hayes (pers. comm.).

LAKE NAME: Little Dixie Lake
LOCATION: Callaway Co., Missouri, USA
SURFACE AREA: 83 ha
MAXIMUM DEPTH: 8.2 m

PROBLEM: Overabundant small bluegills *(Lepomis macrochirus)*, poor growth of largemouth bass *(Micropterus salmoides)*, and decreasing quality of fishing. **RESTORATION OBJECTIVE**: To increase the availability of small bluegills to the largemouth bass by forcing them out of the dense macrophyte beds. To restore a balanced fish population and improve the sport fishery. **RESTORATION METHODOLOGY**: The water level was lowered 2.4 m between 19–29 July, 1964. The impoundment was originally equipped with a drain pipe and gate valve. The surface area was reduced by 42% and the volume, by 58%. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After drawdown there was an increase in largemouth bass food consumption and an increase in their growth rate. Bluegill harvest increased immediately after drawdown but later declined; the reverse was true for the largemouth bass. Forage-sized bluegills (fry and fish up to 10.2 cm in length) were greatly reduced in number as indicated by shoreline seining. The reduction in bluegill numbers was thought due to entrapment in the weed beds and shallow pools, exposure of nests, and largemouth bass predation. **REFERENCES**: Funk (pers. comm.; reports are available), Heman (1965), Heman et al. (1969).

LAKE NAME: Little Dixie
LOCATION: Callaway Co., Missouri, USA
SURFACE AREA: 83 ha
MAXIMUM DEPTH: 8.2 m

PROBLEM: Excessive erosion in the drainage basin. During 1969 and 1970 fishing pressure and harvest were reduced by 18% and 33%, respectively, and the growth rate of largemouth bass *(Micropterus salmoides)* was curtailed due to the very turbid water. **RESTORATION OBJECTIVE**: To reduce the amount of sediment carried into the lake and thus to reduce turbidity and improve fishing. **RESTORATION METHODOLOGY**: About 220 ha of land (94%) was being intensively farmed in the drainage basin. Erosion from this land was composed of very fine clay particles which remained in suspension for a long time. A cooperative management project was initiated to construct terraces, grass waterways, and silt basins on 162 ha of this land. Most of the work was accomplished within a single year at a total cost of about $30,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Since completion of the watershed work, turbidity has remained within normal levels. Fishing pressure has increased by 39% and harvest of fish by 157%. These changes cannot be attributed entirely to improved water clarity, however, and the effectiveness of the work cannot be fully evaluated until extremely wet weather again occurs in the spring and early summer (similar to the 1969 and 1970 climatic conditions). **REFERENCES**: Funk (pers. comm.; reports are available).

LAKE NAME: Little Lake Tangerine
LOCATION: Lake Alfred, Florida, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Cultural eutrophication. Nuisance algal blooms and excessive chiromomid production. **RESTORATION OBJECTIVE**: To reduce the nutrient content of the water. **RESTORATION METHODOLOGY**: Water hyacinths *(Eichornia crassipes)* were harvested mechanically. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Pond studies indicated that hyacinth harvesting could significantly reduce the nutrient levels. The technique was, however, difficult to implement in the field and could not be made operational on a large-scale basis. Optimal harvesting for nutrient removal involved managing the macrophytes on a sustained yield basis. The technique might be more realistically applied in the inflowing streams rather than in the lake. **REFERENCES**: Yount and Crossman (1970).

LAKE NAME: Little Muskego Lake
LOCATION: Waukesha Co., Wisconsin, USA
SURFACE AREA: 2 km^2
MAXIMUM DEPTH: 19.8 m

PROBLEM: Highly eutrophic; algae and macrophyte problems; excessive sedimentation; high in nutrients; poor water clarity; overabundant carp *(Cyprinus carpio)*. **RESTORATION OBJECTIVE**: To reduce the nutrient/sediment input. To deepen the sediment-filled bays. To improve the water clarity and eliminate the carp population. To improve the feeding and spawning conditions for the sport fish. **RESTORATION METHODOLOGY**: A 2.1 m drawdown occurred from fall, 1971 to fall, 1972 (50% reduction in surface area). The lakeshore was completely sewered in 1972 at a cost of $2,000,000 USA. The outlet dam was modified in 1972 at a cost of $50,000 to permit a 0.6 m drawdown each fall. The fish population was eradicated in summer, 1972 at a cost of $35,000 using rotenone (3–4 mg/l) and some antimycin. The lake bottom was cleaned of trash during the drawdown. Artificial spawning beds were placed in the lake at a cost of $1500. Good soil conservation practices in the drainage basin were required through the passage of a governmental ordinance in March, 1973. Dredging is planned for the future at an anticipated cost of $750,000. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The carp were eliminated and the water clarity increased greatly. Over 25 cm of sediment compaction occurred during the drawdown. Various physical, chemical and biological parameters are being monitored, but sufficient time has not elapsed for conclusive results. **REFERENCES**: Druckenmiller (pers. comm.), Ford (pers. comm.; a report is available).

LAKE NAME: Lodge (Loon) Lake*
LOCATION: Ogemaw Co., Michigan, USA
SURFACE AREA: 6.8 ha
MAXIMUM DEPTH: 4.9 m

PROBLEM: Shallow and eutrophic; overabundance of macrophytes. Long history of winterkill. **RESTORATION OBJECTIVE**: To improve the winter dissolved oxygen levels. **RESTORATION METHODOLOGY**: Two different aeration devices were used. During the winters of 1958–1959 and 1959–1960, an 150 m length of perforated air line was placed in the lake and connected to a shore-based compressor rated at 19–25 l/sec. During the first winter, the line was anchored on the lake bottom in water 1–3 m deep, but in 1959–1960 it was suspended at a depth of 1.5 m. During both winters the compressor was operated from December to late March. During the 1962–1963 winter, a floating surface aeration unit drew water in from a depth of about 1.2 m and discharged it as a thin sheet at the surface. Operating costs for the electric motor (power only) were about $7 USA/month, and the aerator was operated for about four months. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During the winters of 1958–1959 and 1959–1960, the aerator maintained a channel of open water about 3–6 m wide across the lake, except during extremely cold weather, when only a series of holes above each perforation remained open. Dissolved oxygen concentrations in the open water were never much higher than in the rest of the lake and were frequently lower. Winterkills were observed during both winters and circulation may have helped cause them. During the winter of 1962–1963, the spray melted an ice-free area about 25 x 12 m. A rapid downward trend in the dissolved oxygen concentrations at the 1.6 m level was observed following start-up of the unit. No similar trend was noted in nearby lakes, and the decline was more severe than during previous winters. Failure of the unit was probably due to its low capacity; it added only 4.8 kg of oxygen/day whereas oxygen consumption was more than twice that amount. **REFERENCES**: Patriarche (1961, 1963a).

LAKE NAME: Long Lake
LOCATION: Dundee, Illinois, USA
SURFACE AREA: 1.7 ha
MAXIMUM DEPTH: 1.8 m

PROBLEM: Overabundant carp *(Cyprinus carpio)* population. **RESTORATION OBJECTIVE**: To test the value of baiting carp with corn as a method of concentrating these fish for easier fish removal (selective removal at minimal cost). **RESTORATION METHODOLOGY**: Presoaked corn was broadcast from a boat in a specfic area of the lake for about 1-1/2 weeks in June–July, 1959 (84 kg). The area was then cordoned off with a tarpaulin and treated with rotenone. The rest of the lake was also treated to determine the effectiveness of the baiting procedure. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Only 25% of the carp population was within the baited area. This was considered insufficient for a lake of this size. Little current was present through the baited area; better results would be expected if the baited area were located in an area of inflow to the lake. A similar percentage of channel catfish *(Ictalurus punctatus)* was inside the baited area. **REFERENCES**: Buck et al. (1960).

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*See also Loon Lake listing

LAKE NAME: Long Lake
LOCATION: Oakland Co., Michigan, USA
SURFACE AREA: 59 ha
MAXIMUM DEPTH: 2.1 m (before deepening)

PROBLEM: Highly eutrophic; shallow (mean depth, under 1 m); extensive macrophyte growths; winterkills. **RESTORATION OBJECTIVE**: To deepen the lake in order to restore its recreational usefulness. **RESTORATION METHODOLOGY**: A 30 cm hydraulic cutterhead dredge was used during 1961–65 to remove an estimated 840,000 m^3 of sediment and to increase the average and maximum lake depths to 2 and 4 m, respectively. The surface area of the lake was enlarged by 4 ha. The total cost of the project was $185,000 USA ($0.22/m^3). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Extensive areas of sandy shoreline were created, and swimming, boating, and fishing conditions have been substantially improved. No winterkill has occurred since dredging, and property values in the area have increased. All vegetation was killed in the 42 ha spoils area, but regrowth is presently taking place. **REFERENCES**: Spitler (pers. comm.; a report is in preparation).

LAKE NAME: Long
LOCATION: Langlade Co., Wisconsin, USA
SURFACE AREA: 27.5 ha
MAXIMUM DEPTH: 6 m

PROBLEM: Occasional winterkill and algal blooms. **RESTORATION OBJECTIVE**: To alleviate the eutrophic conditions and to demonstrate the effects of aluminum ion addition on pH and alkalinity in a soft-water lake. **RESTORATION METHODOLOGY**: Approximately 8,000 l of sodium aluminate and 13,000 l of alum were applied in a liquid form to give an aluminum concentration of 14 mg/l in the upper 0.6 m of the lake water. **RESULTS (OR STATUS FOR ONGOING PROJECTS**: Changes in pH and alkalinity were successfully controlled by combined alum/aluminate treatment. Post-treatment phosphorus concentrations remained low, and during the following winter the dissolved oxygen content of the lake remained at satisfactory levels. **REFERENCES**: Peterson (pers. comm.; a report is in preparation), Smith (pers. comm.).

LAKE NAME: Long Reach Lake
LOCATION: Columbia, Maryland, USA
SURFACE AREA: 1.4 ha
MAXIMUM DEPTH: 4.5 m

PROBLEM: Used as a sediment trap during urban construction in the 80 ha drainage basin. An engineered forebay with a submerged dam was used to settle out sediments prior to their entering the lake. **RESTORATION OBJECTIVE**: To demonstrate the use of a forebay to prevent sedimentation in the lake proper. To remove the trapped sediments from the lake after construction activities were completed. **RESTORATION METHODOLOGY**: Slack line excavation equipment (Sauerman bucket) was used to remove the accumulated sediments. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Accumulated sediments were successfully removed. The project was designed to minimize environmental and aesthetic damage to the shoreline areas and was accomplished with virtually no complaints from residents in the vicinity. **REFERENCES**: Mallory (pers. comm.; a report is in preparation).

LAKE NAME: Loon (Lodge) Lake*
LOCATION: Rifle River area, Michigan, USA
SURFACE AREA: 6.8 ha
MAXIMUM DEPTH: 4.9 m

PROBLEM: Large population of slow-growing pumpkinseed *(Lepomis gibbosus)*. **RESTORATION OBJECTIVE**: To improve the fish growth and angling through population reduction. **RESTORATION METHODOLOGY**: The lake was treated with toxaphene in August, 1958 at an average concentration of 5 µg/l. No attempt was made to estimate the extent of the kill. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During 1959 growth of the young-of-the-year pumpkinseed was unchanged, but some improvement was noted for the older fish. In 1960 the population of pumpkinseeds was near pre-treatment levels; the population of 15.2 cm fish was, however, twice as high. The bluegill *(Lepomis macrochirus)* population was greatly reduced by treatment, but increased growth did not result. Fishing success and catch were poor 1959 through 1961. Interpretation of these population changes was complicated by partial winterkills in 1958-59 and 1959-60. **REFERENCES**: Patriarche (1963b).

LAKE NAME: Lowell Lake
LOCATION: Idaho, USA
SURFACE AREA: —
MAXIMUM DEPTH: —

PROBLEM: Overabundance of undesirable fish species. **RESTORATION OBJECTIVE**: To remove significant numbers of the problem species; to determine the practicality and effectiveness of control methods and the impact upon the sport fishery. **RESTORATION METHODOLOGY**: Various nets and traps were tested in 1955 and 1956. During 1957-59 emulsifiable rotenone (Pro-Noxfish) was applied aerially to concentrations of spawning carp *(Cyprinus carpio)*; various chemical concentrations were used. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Catches were low and inconsistent using the nets and traps. Rotenone concentrations of 1 mg/l were ineffective in killing the carp whereas heavy mortalities occurred at 2 mg/l. Due to the limited proportion of total spawning area actually treated the estimated kill was much less than 50% of the adult population. **REFERENCES**: Keating (1961).

LAKE NAME: Lower Blue Lake
LOCATION: Lake Co., California, USA
SURFACE AREA: 20.3 ha
MAXIMUM DEPTH: 4.6 to 6.1 m

PROBLEM: Excessive eutrophication. **RESTORATION OBJECTIVE**: To demonstrate a biological control for the midge and planktonic algal populations. **RESTORATION METHODOLOGY**: *About 3000 Menidia audens* (Mississippi silversides) were stocked in September, 1967. These young-of-the-year were 50–70 mm in size. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Sampling by seine during 1968 produced several dozen silversides. Their establishment in large numbers seemed likely in this lake. **REFERENCES**: Cook, Jr. and Moore (1970).

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*See also Lodge Lake listing

LAKE NAME: Lower Hollywood Reservoir
LOCATION: Los Angeles, California, USA
SURFACE AREA: 33 ha
MAXIMUM DEPTH: 40 m (full pool)

PROBLEM: Nuisance algal blooms; hypolimnetic oxygen depletion; poor water quality near the bottom. Used as a municipal water supply reservoir. **RESTORATION OBJECTIVE**: To provide a dependable supply of good quality water through the summer. **RESTORATION METHODOLOGY**: In 1953, compressed air was introduced into the hypolimnion in an attempt to mix and aerate the entire lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Although large volumes of water were circulated and the thermocline was definitely lowered, insufficient horizontal movement limited the degree of success. **REFERENCES**: Derby (1956).

LAKE NAME: Lower St. Regis Lake
LOCATION: Franklin Co., New York, USA
SURFACE AREA: 1.8 km^2
MAXIMUM DEPTH: 13 m

PROBLEM: Excessive algal blooms; influx of sewage treatment plant effluent. **RESTORATION OBJECTIVE**: To control eutrophication by limiting the phosphorus input. **RESTORATION METHODOLOGY**: The project was initiated in February, 1972. Phosphorus removal from the sewage effluent began in July. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not available as yet. A wide variety of physical, chemical and biological parameters are under investigation (in the lake and upstream). **REFERENCES**: Fuhs (pers. comm.; reports are available), Hetling (pers. comm.).

LAKE NAME: Lyman Reservoir
LOCATION: Apache Co., Arizona, USA
SURFACE AREA: 5.3 km^2
MAXIMUM DEPTH: 3.7 m

PROBLEM: Overabundant trashfish population. **RESTORATION OBJECTIVE**: To study toxaphene as a possible toxin for fish population control. **RESTORATION METHODOLOGY**: The lake was treated with toxaphene in dust and emulsified form in August, 1951. A concentration of 0.1 mg/l was achieved. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Carp *(Cyprinus carpio)* began dying within 12 hours. The total estimated kill was 199,760 kg. A heavy rain two days after treatment almost completely stopped the fish die-off. Lake drainage later revealed the presence of several fish species in relatively small numbers as compared to the amounts removed by the toxicant. Water clarity (Secchi disk) increased from 15.2 cm to 1.2 m, but plankton blooms occurred during subsequent summers. **REFERENCES**: Hemphill (1954).

LAKE NAME: Lyon County State Lake
LOCATION: Lyon Co., Kansas, USA
SURFACE AREA: 54.7 ha
MAXIMUM DEPTH: 13 m

PROBLEM: Deteriorating sport fishery. **RESTORATION OBJECTIVE**: To rehabilitate the sport fishery. **RESTORATION METHODOLOGY**: In 1962 the lake was drained, leaving about 1 ha of surface. The fish population was removed by seining and poisoning; restocking occurred in 1963. The lake did not refill completely for nearly 32 months. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Variations in physico-chemical conditions, primary productivity, and relative densities of Cladocera and Copepoda were recorded during the period the lake was refilling (1963–1967). Annual mean productivity, phosphate, specific conductance, and dissolved oxygen levels were significantly lower the final year of the study. In general, density and biomass of zooplankton decreased throughout the study. **REFERENCES**: Prophet (pers. comm.), Prophet (1965, 1970), Prophet et al. (1967).

LAKE NAME: Madison lakes (5)*
Kegonsa
Mendota
Monona
Waubesa
Wingra
LOCATION: near Madison, Wisconsin, USA
SURFACE AREA / MAXIMUM DEPTH:

Kegonsa (11 km^2) / 9.5 m
Mendota (39.4 km^2) / 25.5 m
Monona (14 km^2) / 19.5 m
Waubesa (6.6 km^2) / 10.4 m
Wingra (1.4 km^2) / 6.4 m

PROBLEM: Problems associated with excessive eutrophication, esp. overabundant macrophytes and algae. **RESTORATION OBJECTIVE**: To control the vegetation in order to improve the water quality, fisheries, and recreational usage of the lakes. To identify and restrict the nutrient input. To develop improved macrophyte harvesting equipment and methods of processing. **RESTORATION METHODOLOGY**: Copper sulfate was applied by spraying and "bag dragging" for algal control. Mechanical harvesters and arsenical compounds were employed for macrophyte control. Harvesting of about 14.2 km^2 presently costs about $57 USA/ha including operation and amortization of capital investment. Computer analyses are now being used to predict the response of Lake Wingra to various possible future treatments (part of an IBP study). Many other studies are in progress for these lakes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Algae were not entirely eliminated by copper sulfate treatment; however, water clarity was increased greatly. Spraying was most effective against the species that form surface scums whereas "bag dragging" was preferable for the other algal types. Zooplankton populations were not affected adversely, the incidence of *Saprolegnia* fish infections and "swimmers itch" were reduced significantly. The macrophyte harvesting program is ongoing. The areas are definitely more usable after plant removal and there may also be some long-term benefits. Prototype equipment has been developed to travel several times faster than the commercially available equipment and, due to macrophyte volume and weight reductions, the transportation and disposal costs may be reduced by over 80%. In fact these costs may be eliminated completely as a result of increased utilization of the harvested material by local gardeners. In addition, a protein and mineral concentrate has been prepared from the macrophyte juices and at certain times the macrophytes are an excellent source of xanthophyll, a poultry feed additive. **REFERENCES**: Aboaba et al. (1971), Adams (pers. comm.; much information is available), Bruhn, Livermore, and Koegel (pers. comm.), Bruhn et al. (1971), Cottam and Nichols (1970), Domogolla (1926, 1935), Fomin and Bruhn [?], Koegel et al., (1972), Lind and Cottam (1969), Loucks (pers. comm.), McCabe (pers. comm.; much information is available), Mossier (1968), Nichols (1971), Nichols and Cottam (1972), Sonzogni and Lee (in press).

LAKE NAME: Mansion Pond
LOCATION: Allerton Park, Monticello, Illinois, USA
SURFACE AREA: 5300 m^2
MAXIMUM DEPTH: 4.6 m

PROBLEM: Overabundance of curly leaf pondweed *(Potamogeton crispus).* RESTORATION OBJECTIVE: To eliminate the problem macrophyte. **RESTORATION METHODOLOGY**: Both sodium endothall and diquat were used individually since 1960. During 1960-62 two applications were necessary each year. Since 1962 granular endothall was applied twice per year but only to eliminate scattered individual plants. All treatments occurred prior to seed production. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The treatments were successful in controlling macrophyte density; only scattered regrowth occurs each year. In 1972 no regrowth was observed probably due to turbid water. Following *P. crispus* control, *Chara* became very abundant but was reduced through natural die-off and application of an experimental herbicide. **REFERENCES**: Hiltibran (pers comm.), Hiltibran (1963, 1965, 1967, 1968).

LAKE NAME: Lake Marion
LOCATION: Dakota Co., Minnesota, USA
SURFACE AREA: 2.2 km^2
MAXIMUM DEPTH: ---

PROBLEM: Slow-growing panfish population. **RESTORATION OBJECTIVE**: To determine the value of removal as a means of improving the growth and average size of the residual panfish. **RESTORATION METHODOLOGY**: In 1956 28.6 kg/ha of panfish were removed by seining and trapnetting. Subsequent sampling was conducted in 1958. Black crappies *(Pomoxis nigromaculatus)* comprised 11.0 kg/ha and the rest were mostly bluegills *(Lepomis macrochirus).* RESULTS (OR STATUS FOR ONGOING PROJECTS): In 1956 the catch was made up primarily of three-year-old bluegills; in 1958 there was a larger proportion of older fish, mostly five-year-olds. The information indicated an increase in the growth rate, but the change was slight and may have been natural variation. The crappie population statistics were not evaluated in the report. **REFERENCES**: Skidmore (1960).

LAKE NAME: Marion Millpond
LOCATION: Marion, Waupaca Co., Wisconsin, USA
SURFACE AREA: 43.8 ha
MAXIMUM DEPTH: 3.7 m

PROBLEM: Excessive growth of macrophytes and filamentous algae. Slow-growing fish population. **RESTORATION OBJECTIVE**: To restore the scenic and recreational potential of the lake. **RESTORATION METHODOLOGY**: Plastic sheeting was placed on the lake bottom with a sand or gravel blanket on top. The cost was approximately $494 USA/ha. Some dredging was also conducted in select areas. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Good control of macrophytes resulted for two growing seasons after treatment. *Chara* was rapidly invading some areas and the permanence of treatment was questionable. **REFERENCES**: Born et al. (1973b).

LAKE NAME: Martis Creek Lake
LOCATION: Nevada and Placer Cos., California, USA
SURFACE AREA: 3.1 km^2
MAXIMUM DEPTH: 33 m

PROBLEM: Excessive turbidity during construction and following closure of the dam. Turbidity levels up to 46 Jackson Turbidity Units were noted in the new lake. Strict adherence to high water quality standards was required in this drainage basin. **RESTORATION OBJECTIVE**: To keep turbidity at the normal background level of 0-10 Jackson Turbidity Units (JTU). **RESTORATION METHODOLOGY**: The lake was treated with sufficient Purifloc C-31, an organic, water soluble polyelectrolyte to give an average concentration of 5 mg/l. On 29 and 30 October, 1971 a total of 4721.6 kg of Purifloc C-31 was pressure-sprayed into the lake through submerged orifices. Costs including government plant and labor was $9,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Turbidity decreased by 5 JTU after the first six hours and by 1 November, 1971 turbidity in the lake was a maximum of 10 JTU. Water was released from the outlet works beginning 3 November, 1971. During that week, over 1,000 fish died in a 3–3.5 km reach below the dam. Investigations revealed that excessive C-31 was the cause of the fishkill; apparently inadequate dispersal during treatment resulted in lethal concentrations of the chemical. Investigations are continuing into the effects of various concentrations. **REFERENCES**: Weddell (pers. comm.).

LAKE NAME: Mary Lake
LOCATION: Flagstaff, Arizona, USA
SURFACE AREA: 2.8 km^2
MAXIMUM DEPTH: 9.1 m

PROBLEM: High iron and manganese concentrations; taste problems. Used as a municipal water supply. **RESTORATION OBJECTIVE**: To remove the objectionable tastes from the water. **RESTORATION METHODOLOGY**: An aeration system was installed, consisting of a perforated air line and shore-based compressor. The reservoir was aerated from May to September. Total cost of the system was $25,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Objectionable tastes were successfully removed from the water. The system is currently in operation. **REFERENCES**: Voelker (pers. comm.).

LAKE NAME: Mascoma Lake
LOCATION: Grafton Co., New Hampshire, USA
SURFACE AREA: 4.5 km^2
MAXIMUM DEPTH: 20.7 m

PROBLEM: Nuisance blue-green algal blooms (predominantly *Anabaena* and *Aphanizomenon);* moderate interference with recreation. Some tastes and odors in the municipal water supply. **RESTORATION OBJECTIVE**: To control the nuisance algal growth. To improve the recreational potential. To provide good water quality for municipal uses. **RESTORATION METHODOLOGY**: The lake was treated with 3400 kg of copper sulfate in August, 1964; with 2720 kg in June, 1967; and with 3040 kg in August, 1969. All applications were performed by "bag dragging" to evenly distribute the algicide to a 3.1 m depth. Application of copper sulfate at a dosage rate of 6.7 kg/ha cost a total of $2,900 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Chemical treatment provided seasonal control of the nuisance algal blooms. (Permanent improvement appears to have resulted since woolen mill wastes have been eliminated and the phosphate load to the system has been reduced.) **REFERENCES**: Frost (pers. comm.).

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*see also the individual listings for these lakes.

LAKE NAME: Lake Mattamuskeet

LOCATION: Hyde Co., North Carolina, USA
SURFACE AREA: 121.5 km^2
MAXIMUM DEPTH: --

PROBLEM: Poor sport fishing; turbid water; and lack of macrophytes. **RESTORATION OBJECTIVE**: To improve the gamefish population and the waterfowl habitat by carp *(Cyprinus carpio)* removal. **RESTORATION METHODOLOGY**: Barriers were constructed to stop the spawning migration of adult carp, but not gamefish, into the lake. Adult carp removal began in 1940 using fyke and pound nets. In 1949 harvest was greatly intensified by using drag seines in baited areas. Carp were also removed by the commercial fishermen. Summer drawdowns occurred before and during the study period. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There was no apparent reduction in the carp population until 1949. During 1949-52 over 6.81×10^5 kg of carp were captured (28 kg/ha in 1951) including sizable quantity of fingerlings; the water clarity concurrently increased from 15.2 cm to 50–90 cm. A variety of macrophytes also became abundant. In 1951 the condition factors of gamefish showed an improvement and largemouth bass *(Micropterus salmoides)* fingerlings were found for the first time in many years. The gamefish caught by angling in 1952 was 75% above the quantity caught in previous years. **REFERENCES**: Cahoon (1953).

LAKE NAME: Lake Mead

LOCATION: northwestern Arizona, USA
SURFACE AREA: 650 km^2
MAXIMUM DEPTH: 178 m

PROBLEM: Deteriorating water quality due to the influx of nutrients and bacteria. High algal growth rates at one end of the reservoir. **RESTORATION OBJECTIVE**: To determine the effect of heavy recreational usage of a part of the drainage basin. To remove nutrients from one of the inflows. **RESTORATION METHODOLOGY**: The dumping of chemical toilets may be prohibited in the major tributary. The chemical removal of nutrients is tentatively planned for another inflow. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Point sources of high chemical and bacterial levels have been located, but still need to be quantified. Studies are continuing. **REFERENCES**: Everett (pers. comm., [?]).

LAKE NAME: Medina Lake

LOCATION: 40 km NW of San Antonio, Texas, USA
SURFACE AREA: 23.1 km^2
MAXIMUM DEPTH: ---

PROBLEM: Unbalanced fish population, primarily due to overabundant gizzard shad *(Dorosoma cepedianum)*. **RESTORATION OBJECTIVE**: To selectively remove the gizzard shad in order to improve the quality of the sport fishery. **RESTORATION METHODOLOGY**: In November, 1956 the lake was treated with rotenone at a concentration of 0.13 mg/l. At that time the lake was drawn down to 2.2 km^2. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: An estimated 12,485 kg of shad and 4540 kg of carp *(Cyprinus carpio)* were killed (total of 76 kg/ha). Less than 3% of the killed fish were gamefish. Following an initial decrease, a significant increase in angling success occurred in 1957-58. During 1958-59 the gizzard shad population returned to pre-treatment levels and the angler success declined. **REFERENCES**: Dietz and Jurgens (1963).

LAKE NAME: Mendota

LOCATION: Dane Co., Wisconsin, USA
SURFACE AREA: 39.4 km^2
MAXIMUM DEPTH: 25.6 m

PROBLEM: Excessive growths of phytoplankton and macrophytes. Water quality problems associated with overfertilization. **RESTORATION OBJECTIVE**: To reduce the nutrient loading. **RESTORATION METHODOLOGY**: In December, 1971 two small municipalities diverted their sewage from the lake; the sewage from another town will be diverted in the near future. These diversions will reduce the P loading to the lake by an estimated 20%. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The hydraulic residence time is 4.5 yrs. An extensive chemistry monitoring program began in the summer of 1970. The project will continue into future years. No changes have been observed (or expected) as yet. **REFERENCES**: Sonzogni (pers. comm.), Sonzogni and Lee (1972, and in press).

LAKE NAME: Meridian

LOCATION: King Co., Washington, USA
SURFACE AREA: 60 ha
MAXIMUM DEPTH: 28 m

PROBLEM: Advanced mesotrophic state; increased rate of eutrophication induced by the influx of nutrients from septic tanks and urban runoff. **RESTORATION OBJECTIVE**: To reduce the nutrient supply thereby lowering the steady state nutrient concentration in the lake, and therefore the maximum algal biomass. **RESTORATION METHODOLOGY**: An interceptor sewer will be installed around the lake. Wastewaters will be taken from the drainage basin (6.7 km^2) to a nearby treatment facility. Construction should start in early 1973. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A limited monitoring project is being conducted in the lake. **REFERENCES**: Welch (pers. comm.).

LAKE NAME: Meridian State Park Lake

LOCATION: Bosque Co., Texas, USA
SURFACE AREA: 28 ha
MAXIMUM DEPTH: 3.4 m

PROBLEM: Slow-growing white crappies *(Pomoxis annularis)*. **RESTORATION OBJECTIVE**: To evaluate white crappie removal as a method of increasing the growth rate of the remaining crappies. **RESTORATION METHODOLOGY**: The study was conducted during 1967-70. In 1969, 10.7 kg of white crappies/ha were removed from the lake (29.4% reduction in the standing crop) with various types of nets. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The average size of angler-caught white crappies increased from 16.4 cm in 1968 to 20 cm in 1970. The number of crappies caught/hour of angling effort dropped from 0.39 in 1968 to 0.19 in 1970. The weight of crappies removed by angling was 499 kg in 1968 and 359 kg in 1970. The length-weight relationship improved in 1970. The authors discuss other management techniques that might be applied successfully to further enhance control effectiveness. **REFERENCES**: Rutledge and Barron (1972).

LAKE NAME: Metigoshe

LOCATION: North Dakota, USA and Manitoba, Canada
SURFACE AREA: 6.4 km^2
MAXIMUM DEPTH: 6.7 m

PROBLEM: Overabundance of macrophytes (cover approximately 70% of the surface area). Eutrophic problems induced by effluent from cottages and agricultural runoff. **RESTORATION OBJECTIVE**: To limit the macrophyte growths; to make the lake more usable. **RESTORATION METHODOLOGY**: There are no definite plans at this time. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Research is in progress to assess the hydrogeology, biology, and economics of the lake and its drainage basin. A variety of limnological parameters are under investigation, including formulation of a nutrient budget for the lake. **REFERENCES**: Disrud (pers. comm.), Peterka (pers. comm.).

LAKE NAME: Lake Michigan
LOCATION: Illinois, Indiana, Michigan, and Wisconsin, USA
SURFACE AREA: 58,016 km^2
MAXIMUM DEPTH: 281.5 m

PROBLEM: Degradation from industrial and municipal sources, storm and combined sewer discharges, agricultural runoff, and urban sediment. **RESTORATION OBJECTIVE**: To improve the quality of the offshore waters in the southern portion of the lake and of the near shore waters in several areas. **RESTORATION METHODOLOGY**: Municipalities were scheduled to have phosphorus removal facilities (at least 80% of the phosphorus entering the sewage treatment plant) in operation by 1973. Several other abatement measures are being implemented or are under consideration. The water quality of the lake is being investigated by several scientists/agencies. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The hydraulic residence time for the lake is about 100 yrs. The total phosphorus influx is estimated at 8.2 x 10^6 kg/yr; after sewage treatment modification, this value will be reduced by 50 to 60%. Areas that are of particular interest due to severe eutrophication include: 1) the Calumet area on the southern tip of the lake, and 2) Green Bay. Post-treatment results not yet available. **REFERENCES**: Bartsch (1968), Lee (1972), Limnos (1972), Zar et al. (1972).

LAKE NAME: Middle Pond
LOCATION: near Three Forks, Montana, USA
SURFACE AREA: 8.2 ha
MAXIMUM DEPTH: 5.5 m

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To determine some of the changes in limnology that result from the usage of toxicants in fisheries management. **RESTORATION METHODOLOGY**: Chem-Fish Special was used at a concentration of about 0.7 mg/l in July, 1957; this piscicide contained 5.5% rotenone. Pro-Noxfish was used at a concentration of about 0.95 mg/l in September, 1957; this piscicide contained 2.5% rotenone. In October, 1957 toxaphene was used at a concentration of 0.17 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: No living fish were found after the toxaphene treatment; incomplete kills resulted from the other two treatments. The recovered dead fish yielded 60.2 kg/ha, about 90% panfish. Water clarity was 2.7 m initially, 4.4 m after the first treatment, 4.4 m after the second, and more than 5.5 m after the third. Turbidity was 3.8 mg/l initially, 1.75 mg/l after the first treatment, 2.35 mg/l after the second, and 0.85 mg/l after the third. Treatments had little effect on the phytoplankton, although *Ceratium* abundance was reduced. The zooplankton were greatly reduced after the first two treatments with Cladocera eliminated by Pro-Noxfish. No zooplankton were found after treatment with toxaphene. Gastropoda were the only organisms present in littoral collections after the third treatment. Toxaphene reduced Tendipedidae abundance significantly, but Tubificidae became more numerous. **REFERENCES**: Wollitz (1962).

LAKE NAME: Mill Creek Reservoir
LOCATION: Toledo, Oregon, USA
SURFACE AREA: 5.3 ha
MAXIMUM DEPTH: 14 m (full pool)

PROBLEM: Hypolimnetic oxygen depletions and dense growths of algae. Restricted usage of the water for municipal supply. **RESTORATION OBJECTIVE**: To control the algae and oxygenate the bottom waters. **RESTORATION METHODOLOGY**: Destratification was achieved in the summers of 1971 and 1972 using 91 m of perforated plastic tubing suspended 0.7 m above the bottom in the deepest part of the reservoir. Air was supplied from a shore-based compressor at a rate of 38 l/sec, for a period of 10–30 hours each week. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In 1971, the water in the reservoir remained potable for the entire summer and algal blooms were noticeably diminished. In 1972, the water became too colored for general use in mid-August, but this may have been due in part to a drawdown in excess of 7 m. Continued operation is anticipated. **REFERENCES**: Skeesick and Hart (pers. comm.).

LAKE NAME: Mirror Lake
LOCATION: Waupaca Co., Wisconsin, USA
SURFACE AREA: 4.5 ha
MAXIMUM DEPTH: 13 m

PROBLEM: Highly eutrophic; hypolimnetic oxygen depletions; winterkills. Dense algal blooms in summer and winter; deteriorating fishery; and poor water quality. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen regime thereby correcting many of the related problems. **RESTORATION METHODOLOGY**: Two aerators were used. During late summer, 1972, the 1972-73 winter, and the summer of 1973 a hypolimnetic aerator--11 m long, 45 cm diameter "Helixor"–was anchored on the bottom and operated to oxygenate the bottom waters without disrupting the thermal gradients or creating ice-free areas. During the intervening overturn periods, a total aerator was operated to lengthen the period of natural mixing. For both aerators, an electrically-powered compressor was used with a capacity of 8 l/sec, 0.14 kg/cm^2. Pure oxygen was used at the rate of 2.6 l/sec in conjunction with the compressor during two weeks of hypolimnetic aeration in 1972. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In summer, 1972 the hypolimnetic oxygen demand could not be satisfied even while using liquid oxygen; dissolved oxygen levels never exceeded 0.5 mg/l. The temperature of the hypolimnion increased slightly (2° C) during the 30-day aeration period. Phosphate-phosphorus, hydrogen sulfide, and manganese concentrations declined, but rose again after the aerator was shut down. The lake was destratified slightly earlier than normal in the fall of 1972 in order to bring dissolved oxygen levels up to near saturation prior to freeze-up. During the 1972-1973 winter, although oxygen levels were not increased appreciably, the rate of decline was slowed and oxygen was maintained at the mud-water interface. No open water was created during operation. During vernal overturn in 1973 dissolved oxygen levels were again raised to near-saturation values. The hypolimnetic aerator was started in June; the aerator will probably operate more successfully during summer, 1973 due to a decreased oxygen demand. **REFERENCES**: Smith and Knauer (pers. comm.).

LAKE NAME: Mittry Lake

LOCATION: near Yuma, Arizona, USA
SURFACE AREA: 5.3 km^2
MAXIMUM DEPTH: 2.1 to 2.4 m

PROBLEM: Excessive turbidity. Lack of macrophytes. Deteriorating sport fishery. **RESTORATION OBJECTIVE:** To eliminate the large carp *(Cyprinus carpio)* population. **RESTORATION METHODOLOGY:** In April, 1955, toxaphene was dusted on the water surface by airplane. The water level was drawn down leaving 3.2 km^2. Sufficient toxaphene was applied to give an average concentration of 0.5 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Distressed carp were noted 6.5 hrs after application. Fish continued to die for about 1-1/2 weeks; substantial numbers of carp were involved but few gamefish. Various birds fed heavily on the dead fish. The kill was incomplete, however, and a second treatment (similar) was conducted in May, 1955. Distressed carp appeared within 2 hours and killing was complete within 2 days. The water became crystal clear within 4 days, algal blooms developed and large zooplankton of several species became extremely abundant. Small snails and Chiromomids also were abundant. The macrophyte growths expanded rapidly to cover the surface in many spots. **REFERENCES:** Haskell (1955).

LAKE NAME: Lake Mohawk

LOCATION: Sussex Co., New Jersey, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundant growth of macrophytes (*Potamogeton* spp.). **RESTORATION OBJECTIVE:** To remove the macrophytes thereby enhancing the recreational potential of the lake. **RESTORATION METHODOLOGY:** The macrophytes were removed in 1941 by mechanical harvesting. A homemade uprooting device (11.6 m long, 4.9 m wide with a baler) was built at a cost of $4,000 USA. The harvester was operated by a six-man crew. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** All of the macrophytes were removed from the lake by July 1. Eighty bales or 12,700 kg of macrophytes were harvested. **REFERENCES:** Crouse (1941).

LAKE NAME: Mondeaux Flowage

LOCATION: Taylor Co., Wisconsin, USA
SURFACE AREA: 1.7 km^2
MAXIMUM DEPTH: 3.1 m

PROBLEM: Heavy growths of macrophytes, primarily *Potamogeton Robbinsii, Nuphar variegatum*, and *Nymphaea tuberosa.* Macrophytes occupy 95% of the littoral zone in the southern portion of the flowage. **RESTORATION OBJECTIVE:** To increase the recreational (e.g., fishing and boating) potential of the area by controlling the macrophyte growths. **RESTORATION METHODOLOGY:** The water level was lowered 180 cm from November through March in 1971–72 and 1972–73. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** After the first drawdown, only 60% of the littoral zone was occupied by macrophytes. The density declined from over 100 stems/m^2 before drawdown to less than 40 stems/m^2. This condition was maintained by the second drawdown. **REFERENCES:** Nichols (pers. comm.).

LAKE NAME: Monona

LOCATION: Dane Co., Wisconsin, USA
SURFACE AREA: 14 km^2
MAXIMUM DEPTH: 19.5 m

PROBLEM: Excessive blooms of nuisance algal species; overfertilization induced by the influx of sewage effluent. **RESTORATION OBJECTIVE:** To improve the conditions by sewage diversion. **RESTORATION METHODOLOGY:** Complete diversion to a downstream watercourse was accomplished in 1936; some inflow recurred during the 1940's but diversion was otherwise continuous. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Following the final complete diversion in 1950, the mean winter concentration of soluble orthophosphorus in the outlet waters dropped to about 0.04 mg/l. During the previous two winters the average concentration was approximately 0.1 mg/l. Ten years later the average winter values were under 0.04 mg/l. The hydraulic residence time for this lake was 1.1 yrs. Prior to diversion nearly 45,400 kg of $CuSO_4$ were used per year to control the algal growths; however, by 1962 applications were no longer necessary. Large algal populations still occur but nuisance species no longer predominate. **REFERENCES:** Edmondson (1969), Sonzogni and Lee (1972).

LAKE NAME: Montezuma National Wildlife Refuge Ponds

LOCATION: Seneca Falls, New York, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of cattail *(Typha latifolia* and *T. angustifolia).* Poor wildlife habitat. **RESTORATION OBJECTIVE:** To decrease the cattail density. **RESTORATION METHODOLOGY:** Various degrees of flooding were accomplished using low cost management structures. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The cattails were successfully controlled by increasing the water depth: 1) 45.7 cm eliminated plants under one year old, 2) 45.7–50.8 cm prevented the spread of second year growth, 3) 50.8–63.5 cm yielded a partial kill of established plants; and 4) over 63.5 cm gave a complete kill. **REFERENCES:** Steenis et al. (1958).

LAKE NAME: Morineeka

LOCATION: Trempealeau Co., Wisconsin, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of the American water lotus *(Nelumbo lutea).* About one-third of the surface area was covered by this macrophyte. **RESTORATION OBJECTIVE:** To control macrophyte growth in a 6080 m^2 area in order to improve user access to open water. **RESTORATION METHODOLOGY:** In June when the macrophyte leaves were emerging, 680 kg of silvex pellets were scattered in the area. A follow-up spraying with silvex liquid was done at a rate of 18.7 l/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Five days after the second treatment, a 100% kill was noted in the treated area; only a small percentage were killed along the fringe. Direct application to the macrophytes was not important; however, the concentration in the surrounding water had to be about 2-3 mg/l after at least two treatments within 14 days. Fish mortalities were not observed. Other studies have shown the same treatment to be 100% effective against all species of water lilies, providing the water depth is under 1.2 m. **REFERENCES:** Schein (pers. comm.).

LAKE NAME: Moses Lake

LOCATION: east of Seattle, Washington, USA
SURFACE AREA: 27.5 km^2
MAXIMUM DEPTH: 11.5 m

PROBLEM: Nuisance blue-green algal blooms; restricted recreational usage of the lake. **RESTORATION OBJECTIVE**: To reduce the algal growth and biomass and to increase the recreational potential. To determine the effect of low nutrient water additions on the algae in terms of physical washout and nutrient dilution. **RESTORATION METHODOLOGY**: Irrigation water was diverted into a small portion of the lake; the flushing water equalled 6% by volume of the lake area studied. About 5.8×10^5 m^3 of water was introduced at a cost near $0.71 USA/$10^3$ m^3. Flushing water was added for one 24 hour period in September, 1967. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The flushing water was more dense than the lake water and flowed along the bottom, resulting in inefficient dilution/flushing. Dissolved oxygen concentrations increased near the bottom but decreased near the surface. Soluble P concentrations decreased somewhat near the bottom but increased near the surface. The effect on N was undeterminable due to prevailing lake conditions. Due to bottom flow, algal density was not affected significantly. In-situ experimentation indicated that the maximum biomass of nuisance blue-green algae would decrease in direct proportion to the amount of dilution; there would be no effect on green algae or diatoms. The future, large-scale addition of low-nutrient water from a nearby river was recommended, although other measures were being considered. **REFERENCES**: Buckley (1971), Bush and Welch (pers. comm.), Bush and Welch (1971), Nunnallee (1968), Sylvester and Oglesby (1964), Welch et al. (1969, 1971, 1972a).

LAKE NAME: Mud Lake

LOCATION: Washtenaw Co., Michigan, USA
SURFACE AREA: 36 ha
MAXIMUM DEPTH: 2.1 m

PROBLEM: Periodic winterkills due to oxygen depletion. **RESTORATION OBJECTIVE**: To increase the oxygen levels of the water in order to prevent winterkill. **RESTORATION METHODOLOGY**: During the winter of 1963, four outboard motors were mounted above holes chopped through the ice. The propellers extended into the water, and during operation, they pumped water onto the ice surface. The water flowed over the ice for a distance of about 60 m and re-entered the lake through several drain holes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After about 4.5 hrs of operation, the dissolved oxygen concentrations in the immediate area increased from 2-3 mg/l to 5-8 mg/l at a depth of 0.5 m and to 3-5 mg/l at a depth of 0.9 m. The motors were shut down, but the water with high dissolved oxygen content continued to spread throughout the lake. Four days after aeration the dissolved oxygen concentrations at a depth of 0.5 m showed a general increase throughout the lake. The oxygen concentrations did not reach a critical level for the remainder of the winter. **REFERENCES**: Merna (1965).

LAKE NAME: Murphy Flowage

LOCATION: Rusk Co., Wisconsin, USA
SURFACE AREA: 72.9 ha
MAXIMUM DEPTH: 4.3 m

PROBLEM: Overabundant slow-growing bluegill *(Lepomis macrochirus)* population. **RESTORATION OBJECTIVE**: To determine the effect of liberalized fishing regulations on the bluegill population and the sport fishery. To initiate a removal program in order to study the effect on growth rates. **RESTORATION METHODOLOGY**: Since 30 April, 1955 all fishing was done by special permit with no size, season, or bag limits. The total fishing effort and catch was recorded. In May and June, 1960-61 several panfish species were removed by netting and electrofishing. The first year 52.7 kg/ha were removed and the second year, 46.4 kg/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The bluegill catch increased each year, from 11,100 in 1955-56 to 37,100 in 1958-59. A 25 fish daily bag limit would have reduced the catch by 11-18%. The population was not depleted by liberalized fishing and slow growth continued to be a problem. Mechanical harvesting reduced the bluegill standing crop by 26% each year. The percentage increased with size, 3% for 10.2–11.2 cm to 51% for 16.5–17.5 cm. Between 1960 and 1962 there was a 45% decrease in bluegills over 12.7 cm and a 70% increase in 10.2–12.4 cm fish. There was a continued decrease in rate of growth. These changes caused a deterioration of the sport fishery. **REFERENCES**: Snow (1960, 1962).

LAKE NAME: Murphy Flowage

LOCATION: Rusk Co., Wisconsin, USA
SURFACE AREA: 72.9 ha
MAXIMUM DEPTH: 4.3 m

PROBLEM: Slow-growing bluegills *(Lepomis macrochirus)*. Dense submergent macrophytes, primarily *Nuphar* spp. and *Potamogeton Robbinsii*. **RESTORATION OBJECTIVE**: To reduce the macrophyte growths thereby improving fishing, swimming, and boating conditions. To increase the bluegill growth rate. **RESTORATION METHODOLOGY**: Drawdowns occurred in 1967, 1968, and 1969. Usually the water level was dropped in late October and maintained 1.5 m below normal until the next March. The surface area and total water volume were reduced by 45 and 70%, respectively. There was little or no direct cost. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Before drawdown 32 ha were choked with vegetation. Two summers later this was reduced to only 4 ha. Some species were resistant to drawdown and others reinvaded quickly. Planktonic algal blooms were experienced one year after reduction of the macrophytes. The primary predator species, northern pike *(Esox lucius)*, increased their feeding activities during each drawdown. However, based on data extrapolations the small bluegills apparently outnumbered the northern pike by about 417 to 1 and the increased predation probably had no effect on the dynamics of the bluegill population. After drawdown the consumption of bluegills by largemouth bass *(Micropterus salmoides)* increased greatly, apparently due to an increased accessibility of and preference for bluegills (macrophyte densities were reduced by drawdown) and to a reduction in other foods. There was a drastic reduction in the young bluegills in two out of the three years of drawdown. There was also a slight increase in the abundance of larger bluegills. **REFERENCES**: Beard (pers. comm.), Beard (1969, 1971, 1973), Snow (pers. comm.), Snow (1971).

LAKE NAME: Lake Murray

LOCATION: Carter and Love Cos., Oklahoma, USA
SURFACE AREA: 23.2 km^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundant gizzard shad *(Dorosoma cepedianum)* population; poor fishing success. **RESTORATION OBJECTIVE**: To selectively remove the gizzard shad. **RESTORATION METHODOLOGY**: Emulsifiable rotenone was applied aerially in April, 1955. The cost was $13,500 USA ($5.80/ha); 7570 l were applied in the lake. Studies were conducted through 1956. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The percentage (by weight) of gizzard shad in the total fish population decreased from 60.3% in 1950 to 49% in 1955 and 46% in 1956. No significant changes in growth were noted for any of the fish species present. **REFERENCES**: Sandoz (1956).

LAKE NAME: Muskegon

LOCATION: Muskegon Co., Michigan, USA
SURFACE AREA: 16.8 km^2
MAXIMUM DEPTH: 21.4 to 24.1 m

PROBLEM: Poor water quality resulting from the influx of industrial and municipal wastewater effluents–siltation, algal blooms, odor, low DO, and turbidity. **RESTORATION OBJECTIVE**: To eliminate the influx of wastewater effluents in order to improve water quality and enhance recreational usage of the lake. **RESTORATION METHODOLOGY**: The wastewater inputs will be diverted to a land disposal system at a cost of about $40,000,000 USA. The treatment system should be in operation by the summer of 1973. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Evaluation and modeling studies are in progress as a part of the land disposal program and the water quality monitoring program. **REFERENCES**: Arnold (pers. comm.), Canale (pers. comm.), Koerper (pers. comm.), West Michigan Shoreline Regional Planning Commission (1971).

LAKE NAME: Needwood Lake

LOCATION: Montgomery Co., Maryland, USA
SURFACE AREA: 30 ha
MAXIMUM DEPTH: 7.5 m

PROBLEM: Rapid accumulation of silt. Eutrophic conditions induced by urban development of the drainage basin. **RESTORATION OBJECTIVE**: To prevent the influx of sediment during storm runoff by treatment of the inflow. **RESTORATION METHODOLOGY**: Purifloc C-31 is added to the two main inflows via an automatic pumping system that operates only during high flow periods. The flocculant costs about $1.25 USA/l with roughly 3000 l used each year. The treatment facility cost an additional $25,000; however, this is a pilot project and costs may not be representative. The flocculated materials precipitate in a forebay that is dredged whenever necessary, usually every two years. The lake is drawn down 1.8 m to facilitate the sediment removal. The two dredging operations necessary to date cost $8,253 and $18,580. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Turbidity is decreased as a result of flocculation of the sediment-laden inflow. Turbidity exists in the forebay after abnormal rainfall but the lake proper remains aesthetically pleasant. Bacteria are also removed by the flocculant. The first forebay dredging operation in December, 1969 removed 5040 m^3 of sediment of which 84% was flocculated. Life expectancy of the lake has been increased by at least three-fold. No adverse ecological consequences have been observed as a result of flocculation/lake dredging. **REFERENCES**: Dorsey (pers. comm.), Goddard and Schaefer (undated), Katzer and Pollack (1968), The Dow Chemical Company (undated), Young (1970).

LAKE NAME: Neff Lake

LOCATION: Weld Co., Colorado, USA
SURFACE AREA: 18.2 ha
MAXIMUM DEPTH: 4.6 m

PROBLEM: Overabundant carp *(Cyprinus carpio)* and small crappies *(Pomoxis* spp.). Excessive turbidity and a lack of macrophytes. **RESTORATION OBJECTIVE**: To eliminate part of the fish population by selective poisoning. **RESTORATION METHODOLOGY**: Treatment occurred in September, 1952 using rotenone. About 45.4 kg rolled oats were soaked overnight and applied to a part of the lake. Several hours later a gill net was used to cordon off that portion. The rotenone was then applied by boat. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: High winds caused the treated waters to mix with the rest of the lake resulting in a nearly complete kill. Netting surveys subsequently caught only a few fish. In 1953 the water clarity increased to more than 4.6 m; macrophytes began to develop; and the restocked fish exhibited excellent growth. **REFERENCES**: Evans (1954).

LAKE NAME: Nevin fish pond (1)

LOCATION: Madison, Wisconsin, USA
SURFACE AREA: 1485 m^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundant macrophytes, primarily *Anacharis canadensis, Potamogeton foliosus, P. Richardsonnii,* and *Ceratophyllum demersum*. **RESTORATION OBJECTIVE**: To evaluate the common carp *(Cyprinus carpio)* as a biological macrophyte control agent. **RESTORATION METHODOLOGY**: The pond was divided into two equal sections and one side was stocked with 14 adult fish (about 530 kg/ha). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Partial control of the macrophytes was achieved through grazing and uprooting. *Potamogeton foliosus* and *Ceratophyllum demersum* were the most susceptible species. *Anacharis canadensis* was not affected. **REFERENCES**: Black (1946).

LAKE NAME: Nimrod

LOCATION: Yell and Peery Cos., Arkansas, USA
SURFACE AREA: 14.6 km^2
MAXIMUM DEPTH: ---

PROBLEM: Deteriorating sport fishery; overabundant trashfish species. **RESTORATION OBJECTIVE**: To reduce the trashfish population. To improve the sport fishery. To aerate and consolidate the sediments. **RESTORATION METHODOLOGY**: Fall/winter drawdowns were implemented in 1955 and 1956. The lake was lowered 3.7 m (surface area reduced to 2.8 km^2) each year. Undesirable species were removed by netting during the drawdown period and rye grass was planted on the exposed sediments. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 93,000 kg of fish were removed during the 1955 drawdown (approx. 2270 kg of gamefish were also caught and released). After this drawdown, the water clarity increased from 10.2–30.5 cm to 91.5–122 cm; the sport fishery improved; and there was an increased survival and growth of the gamefish species. During the second drawdown, the weight of fish removed equalled only about one-third that taken during the first drawdown due to a reduced effort. These fish were in very good condition. The percentage of gamefish caught and released was 34% by number and 17% by weight. **REFERENCES**: Crawford (1957), Hulsey (1956).

LAKE NAME: Oakland Lake

LOCATION: Coles Co., Illinois, USA
SURFACE AREA: 10.5 ha
MAXIMUM DEPTH: 4.5 m

PROBLEM: Excessive accumulation of sediments; loss of water storage capacity. Used as a municipal water supply reservoir. **RESTORATION OBJECTIVE**: To deepen the lake in order to increase the storage capacity. **RESTORATION METHODOLOGY**: Dredging began in the summer of 1972. Spoils are being disposed of in a diked-off area which will be developed into a subdivision. The purchase price of the dredge was approximately $70,000 USA. Operating costs are not available, but preliminary data indicates that the cost of removal is about $0.65/m^3$. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 23,000 m^3 of sediment were removed from the lake during four months of operation in 1972. Definite results are not yet available. **REFERENCES**: Roberts (pers. comm.; reports are available).

LAKE NAME: Occoquan Reservoir
LOCATION: Fairfax Co., Virginia, USA
SURFACE AREA: 6.9 km^2
MAXIMUM DEPTH: 19.8 m

PROBLEM: Nuisance algal blooms; hypolimnetic oxygen depletion; high nutrient content; presence of hydrogen sulfide; and taste and odor problems. Apparently induced by the influx of municipal wastes and urban runoff. **RESTORATION OBJECTIVE**: To improve the water quality and existing conditions in general. To limit the sediment input. **RESTORATION METHODOLOGY**: A regional wastewater treatment plant will be constructed for nutrient removal at an estimated cost of $41,500,000 USA. An erosion control program will be initiated in the drainage basin. An aeration/circulation system was installed in 1970 at a cost of $35,500. Some algicides were also applied to the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Aeration during 1970-71 resulted in: 1) increased dissolved oxygen levels and elimination of hydrogen sulfide, 2) reduction in problems associated with water treatment for domestic usage, and 3) absence of nuisance algal blooms. Results are not available for the other studies. **REFERENCES**: Eunpu (pers. comm.), Eunpu (1971), Jensen (pers. comm.), Metcalf and Eddy Engineers (1970), Randall (pers. comm.; reports are available).

LAKE NAME: Oneida
LOCATION: central New York, USA
SURFACE AREA: 206.7 km^2
MAXIMUM DEPTH: 16.8 m

PROBLEM: Nuisance blue-green algal blooms. **RESTORATION OBJECTIVE**: To limit the algal blooms by reducing the nutrient input. **RESTORATION METHODOLOGY**: A channel will be dredged around one side of the lake to divert the inflowing streams away from the lake to the downstream area. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Limnological investigations have included a variety of physico-chemical and biological parameters. Measurements are being taken in the lake and in the drainage basin. Nutrient budgets have been estimated. At the present, about 2.3 and 2.5 metric tons per day of PO_4 and N, respectively enter the lake. Diversion is expected to reduce the influx of PO_4 by 45% and N by 36%. The hydraulic residence time is now 235 days. Effective mixing occurs to a depth of about 9.2 m during the stratification period. **REFERENCES**: Auer (pers. comm.), Ehlke (pers. comm.), Greeson (pers. comm.), Greeson (1971).

LAKE NAME: Onized Lake
LOCATION: near Alton, Illinois, USA
SURFACE AREA: 8000 m^2
MAXIMUM DEPTH: 6.4 m

PROBLEM: Maintenance of a high quality sport fishery. **RESTORATION OBJECTIVE**: To evaluate the effects of liberalized fishing regulations on the bluegill *(Lepomis macrochirus)* population. **RESTORATION METHODOLOGY**: The lake was opened to fishing in 1937. A creel census was operated from Sept., 1938 through June, 1941. Liberalized regulations were in effect through the end of the study. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The yield was 393 kg/ha in 1939, but dropped to 160 kg/ha in 1940. The fishing pressure was 3490 man-hours/ha the first year and 4070 man-hours/ha in 1940. Netting in 1940 indicated a smaller population of large-sized bluegills as compared to 1938. Fish were slow growing the first year but later exhibited exceptionally rapid growth. The fish continued to reproduce successfully; under reduced fishing intensity the lake would probably quickly contain an overabundance of slow growing fish. **REFERENCES**: Bennett (1945).

LAKE NAME: Onondaga Lake
LOCATION: Onondaga Co., New York, USA
SURFACE AREA: 11.5 km^2
MAXIMUM DEPTH: 22 m

PROBLEM: Nuisance green and blue-green algal blooms; lack of DO in the hypolimnion; bacterial contamination from the combined sewer outflows. Heavily polluted by industrial and domestic wastes. **RESTORATION OBJECTIVE**: To reduce the influx of pollutants. To improve the water quality to levels required for contact recreation. **RESTORATION METHODOLOGY**: Tertiary treatment facilities are under construction. The phosphorus and organic inputs will be reduced by 60 and 70%, respectively. Operation should begin in 1977. Combined sewer overflows will also be purified; a demonstration project should be completed by 1975. The usage of phosphorus detergents is now regulated; the phosphorus content was limited to 8.7% in July, 1971 and zero in June, 1973. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The effect of phosphorus reduction in detergents has been pronounced. Between January, 1970 and January, 1973 the concentration of condensed inorganic phosphorus dropped 85 and 76% in the epilimnion and hypolimnion, respectively. And in 1972 *Aphanizomenon* was absent from the usual algal succession. Green algae dominated through the summer and the diversity index was higher than during the previous years. **REFERENCES**: Gilardi (pers. comm.; reports are available), Moffa, (pers. comm.; reports are available), Moffa et al. (1971), Murphy, Jr. (1973), Murphy, Jr. et al. (1973), Onondaga County, Dept. of Public Works and O'Brien and Gere Engineers, Inc. (1971), Sze (pers. comm.), Sze and Kingsbury (1972).

LAKE NAME: Osceola
LOCATION: Coral Gables, Florida, USA
SURFACE AREA: 1.2 ha
MAXIMUM DEPTH: 4.5 m

PROBLEM: Eutrophic due to the influx of nutrient-rich runoff. **RESTORATION OBJECTIVE**: To remove the nutrients by chemical precipitation. **RESTORATION METHODOLOGY**: Aluminum salts or clays will be applied to the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Preliminary laboratory studies are underway. Background chemical and biological data are being collected on the lake. Results are not yet available. **REFERENCES**: Waite (pers. comm.).

LAKE NAME: Ottoville Quarry Lake
LOCATION: Putnam Co., Ohio, USA
SURFACE AREA: 7200 m^2
MAXIMUM DEPTH: 17 m

PROBLEM: Rapid oxygen depletion during summer stratification. The lower 13 m are uninhabitable by fish from June through September. **RESTORATION OBJECTIVE:** To improve the dissolved oxygen regime in order to provide increased living space for the fish (mainly salmonids). **RESTORATION METHODOLOGY:** In 1970 and 1971, the lake was destratified by releasing compressed air through diffusers at the bottom. In 1972, a hypolimnetic aeration system was installed, consisting of a modified air-lift pump. In conjunction with the hypolimnetic aerator, potassium permanganate was added at a concentration of 5 mg/l in an attempt to reduce the biological oxygen demand. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Destratification increased the dissolved oxygen concentration to satisfactory levels, but the water temperatures rapidly passed the optimum for rainbow trout *(Salmo gairdnerii)*. The hypolimnetic aerator did not increase water temperatures appreciably and added large amounts of oxygen to the water passing through the aerator, but the output was too low (1.3 l/sec) to make significant improvements. **REFERENCES:** Gartman (pers. comm.).

LAKE NAME: Owasco Lake
LOCATION: Cayuga Co., New York, USA
SURFACE AREA: 26.7 km^2
MAXIMUM DEPTH: 54 m

PROBLEM: Mesotrophic lake with occasional nuisance blooms of phytoplankton during the summer. **RESTORATION OBJECTIVE:** To determine the effects of a reduction in the phosphorus input. **RESTORATION METHODOLOGY:** In June, 1973 the usage of phosphate detergents will be banned. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Several limnological parameters are under study. The lake is known to be phosphorus limited. **REFERENCES:** Child and Oglesby (1970), Child et al. (1971), Oglesby (pers. comm.).

LAKE NAME: Oxbow Lake
LOCATION: Dundee, Illinois, USA
SURFACE AREA: 5700 m^2
MAXIMUM DEPTH: 2.3 m

PROBLEM: Overabundant carp *(Cyprinus carpio)* population. **RESTORATION OBJECTIVE:** To determine the value of baiting carp with corn as a method of concentrating these fish for easier removal. To selectively remove these fish at minimal cost. **RESTORATION METHODOLOGY:** Presoaked corn was broadcast from a boat into a specific area of the lake for about 1-1/2 weeks in June–July, 1959 (75 kg). The area was then cordoned off with a tarpaulin and treated with rotenone. The rest of the lake was also treated to determine the effectiveness of the baiting procedures. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The baited area contained 93.6% of the lake's carp population. The population was reduced by 489 kg/ha. The baited area also contained 100% of the channel catfish and bullheads (*Ictalurus* spp.), and 0% of the white suckers *(Catostomus commersonnii)* in the lake. **REFERENCES:** Buck et al. (1960).

LAKE NAME: Parvin Lake
LOCATION: Larimer Co., Colorado, USA
SURFACE AREA: 19 ha
MAXIMUM DEPTH: 10 m

PROBLEM: Oxygen depletion in the summer (hypolimnion) and in the winter. **RESTORATION OBJECTIVE:** To assess the limnological effects of artificial aeration/circulation of the lake. **RESTORATION METHODOLOGY:** The aeration system consisted of two 2.75 m long "Helixors" placed in the deeper part of the lake. Air was supplied via weighted plastic tubing from a shore-based compressor rated at 33 l/sec, 4.2 kg/cm^2. The compressor was operated continuously for one year from November, 1969 to October, 1970. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Aeration resulted in almost complete elimination of thermal gradients and dissolved oxygen concentrations remained above 6 mg/l for nearly the entire summer. However, during July and August, dissolved oxygen concentrations as low as 4 mg/l were noted in the bottom waters. During the winter, the aeration system maintained ice-free areas about 200–300 m in diameter above each "Helixor". Iron and manganese concentrations were lower during the entire period of aeration, and the seasonal cycle and depth distribution of other ions was less pronounced than during previous years. Total residue did not increase and seston decreased during aeration. **REFERENCES:** Holmes (pers. comm.), Lackey (pers. comm.), Lackey (1971, 1972 a and b, 1973), Lackey and Holmes (1972).

LAKE NAME: Pasinkis Pond
LOCATION: Livingston Co., Michigan, USA
SURFACE AREA: 1.5 ha
MAXIMUM DEPTH: 1.5 m

PROBLEM: Periodic winterkills due to shallow water, decomposition of extensive macrophyte growths, and highly organic bottom sediments. **RESTORATION OBJECTIVE:** To maintain high dissolved oxygen concentrations during the winter. **RESTORATION METHODOLOGY:** During the winter of 1940, well water was discharged into the lake via an aeration chute. Water was pumped at about 3.2 l/sec for seven days in February and again for seven days in March. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The aeration technique had little effect on in-lake dissolved oxygen conditions. No increase was observed, presumably due to a very high oxygen demand. A winterkill of bluegills, *Lepomis macrochirus* (complete kill) and bullheads, *Ictalurus* sp. (partial kill) occurred during the aeration period. **REFERENCES:** Greenbank (1945).

LAKE NAME: Penacook Lake
LOCATION: Merrimack Co., New Hampshire, USA
SURFACE AREA: 1.5 km^2
MAXIMUM DEPTH: 22.6 m

PROBLEM: Nuisance blooms of blue-green algae; taste and odor problems. Used for municipal water supply. **RESTORATION OBJECTIVE:** To control the nuisance algal growth by application of an algicide. **RESTORATION METHODOLOGY:** Treatments with 1040 kg of copper sulfate took place during 1961-63. The algicide was evenly distributed to the 3.1 m depth (concentration of 0.25 mg/l) by "bag dragging". Chemical costs were $305 USA/treatment. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Chemical treatment provided temporary restoration of water quality. Taste and odor problems were reduced after treatment. A few suckers *(Catostomus commersonnii)* and hornpout *(Ictalurus* *nebulosus)* succumbed during most of the treatments. **REFERENCES**: Frost (pers. comm.).

LAKE NAME: Petrey Pond
LOCATION: southern USA
SURFACE AREA: 1.1 ha
MAXIMUM DEPTH: 2.4 m

PROBLEM: Overcrowded, slow-growing panfish; unbalanced fish population. **RESTORATION OBJECTIVE**: To test the effectiveness of a new piscicide--antimycin--for selectively thinning the overabundant species. **RESTORATION METHODOLOGY**: The liquid formulation of antimycin, Fintrol-Concentrate, was used in the shallow area of the pond. About 38% of the pond was treated on 26 March and 9 April, 1968. The concentration was 0.6 μg/l and 1.0 μg/l for the first and second treatments, respectively. The toxicant was spilled on the pond surface in front of a moving boat. The cost of the toxicant used in the first treatment was $2.40 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The first kill, 24.6 kg/ha, was composed of 99.1% panfish under 12.7 cm in length. No gamefish were eliminated from the pond. The second kill, 47.8 kg/ha, consisted of almost 100% panfish under 12.7 cm in length. About 10-11 kg of golden shiners *(Notemigonus crysoleucas)* and one largemouth bass *(Micropterus salmoides)* also died during the treatments. **REFERENCES**: Burress (1970).

LAKE NAME: Pickerel
LOCATION: Portage Co., Wisconsin, USA
SURFACE AREA: 20 ha
MAXIMUM DEPTH: 5 m

PROBLEM: Nuisance blooms of blue-green algae in summer and green algae in late fall. Periodic occurrence of winterkill conditions. **RESTORATION OBJECTIVE**: To limit phytoplankton production and biomass by reducing the phosphorus availability. **RESTORATION METHODOLOGY**: Liquid aluminum sulfate was applied in April, 1973 to yield a concentration of 7 mg Al/l of lake water (162 kg Al/ha). The liquid was released near the surface and at mid-depth. The chemical costs were $90 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Preliminary results indicate that primary production was decreased during the subsequent summer, at least partly due to a shift in dominant algae from *Anabaena* and *Ankistrodesmus* to *Microcystis;* however, phosphorus concentrations were little changed from the previous year. Data collection and analyses are continuing. **REFERENCES**: Knauer (pers. comm.; a report is in preparation).

LAKE NAME: Plainsboro Pond
LOCATION: Plainsboro, New Jersey, USA
SURFACE AREA: 14 ha
MAXIMUM DEPTH: 1 m (before deepening)

PROBLEM: Excessive accumulation of sediments; shallow water and extensive macrophyte growths. **RESTORATION OBJECTIVE**: To increase the water depth in order to reduce the macrophyte growths, improve the fishery, and make the pond more attractive to users. **RESTORATION METHODOLOGY**: A dragline was used to remove accumulated sediments from the bottom of the entire pond. The creation of two islands permitted draglining in the center of the pond; spoils were placed on the banks. The project was completed in 1972 at a total cost of $148,166.03 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Most of the pond bottom was deepened 1-2 m with some areas by 3 m. The macrophytes were reduced; the sport fishery improved; the waterfowl population increased; and the overall appearance of the pond was enhanced. After leveling and planting the spoil areas were converted into parks. **REFERENCES**: Clark (pers. comm.).

LAKE NAME: Pocono Lake
LOCATION: Monroe Co., Pennsylvania, USA
SURFACE AREA: 3 km^2
MAXIMUM DEPTH: 9 m

PROBLEM: Steady decline in the sport fishery; increased incidence of algal blooms; and overabundance of carp *(Cyprinus carpio).* **RESTORATION OBJECTIVE**: To limit the algal growth by removal of the nutrient sources; to restore the spawning habitat for gamefish; to remove the carp; and to reduce the population of panfish. **RESTORATION METHODOLOGY**: The lake level will be lowered for an extended period with downstream flushing of the natural sludge sediments. The shorelines will be contoured to divert storm drainage. The fish population will be manipulated through : 1) selective netting and removal, 2) drawdown to limit the reproduction of undesirable species, and 3) restriction of the harvest of predator species (*Esox* spp.). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Drawdown is underway with refilling scheduled for spring, 1973. Results are not yet available. **REFERENCES**: MacNamara (pers. comm.).

LAKE NAME: Pomps Pond
LOCATION: Andover Massachusetts, USA
SURFACE AREA: 8 ha
MAXIMUM DEPTH: 3 m

PROBLEM: Excessive accumulation of highly flocculant and easily disturbed sediments. Declining water levels during the summer are also a major problem. **RESTORATION OBJECTIVE**: To remove the sediments in the bathing area and to stabilize the water levels. **RESTORATION METHODOLOGY**: The water levels were maintained by diverting well water into the pond during the recreational season. Work was done at a cost of about $10,000 USA. A drawdown is proposed to permit the removal of about 2000 m^3 of sediments from the 30 x 90 m beach area and replacement with sand. A high-capacity, portable pump combined with partial gravity draining will be used to lower the lake level. The estimated cost is about $5000. A low, partially submerged sand berm is also planned around the perimeter of the bathing area in order to prevent future siltation. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Improved conditions resulted from the stabilized water levels. Drawdown and sediment removal is planned for 1973. **REFERENCES**: McQuade (pers. comm.), Soule (pers. comm.).

LAKE NAME: Porters Lake
LOCATION: Waushara Co., Wisconsin, USA
SURFACE AREA: 31 ha
MAXIMUM DEPTH: 4.9 m

PROBLEM: Overabundant population of small bluegills *(Lepomis macrochirus).* **RESTORATION OBJECTIVE**: To eliminate part of the bluegill population. **RESTORATION METHODOLOGY**: Toxaphene (Coopertox No. 6) was applied to the epilimnion in May, 1962 at an average concentration of 6.25 μg/l. Limnological studies were conducted before and after application; part of the population of fish above 7.6 cm in length were marked prior to treatment. Dead fish were examined after treatment. Predator fish species were stocked in late summer (northern pike, *Esox lucius* and largemouth bass, *Micropterus salmoides*). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The bluegill population was reduced by about 24% (fish above 7.6 cm in length). One year later bluegills in the 7.6 to 11.4 cm size range were few in number indicating heavy mortality of small bluegills in 1962; the length-weight relationship improved after treatment. **REFERENCES**: Primising and Hacker (1964a).

LAKE NAME: Powderhorn
LOCATION: Minneapolis, Minnesota, USA
SURFACE AREA: 3.2 ha
MAXIMUM DEPTH: 7 m

PROBLEM: High algal productivity; turbid water. **RESTORATION OBJECTIVE**: To increase the water clarity by reducing the algal population. **RESTORATION METHODOLOGY**: Flocculation of suspended solids and precipitation of dissolved phosphate was attempted using aluminum sulfate. The slurry was sprayed on the surface in August (785 kg/ha) and October (1120 kg/ha), 1972. Each of the treatments cost about $900 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: There was no visible or measured success. Floc formation occurred but a sustained removal of algae did not result. Some interference may have arisen from the large population of resident goldfish *(Carassius auratus)*. **REFERENCES**: Lundquist (pers. comm.).

LAKE NAME: Province Lake
LOCATION: Carroll Co., New Hampshire, USA
SURFACE AREA: 4.1 km^2
MAXIMUM DEPTH: 5.2 m

PROBLEM: Nuisance blue-green algal blooms (predominantly *Anabaena* and *Aphanizomenon*). **RESTORATION OBJECTIVE**: To control the planktonic algal growth and to improve the water quality for all uses. **RESTORATION METHODOLOGY**: The lake was treated with 1410 kg of copper sulfate in June, 1965 and with 1360 kg in July, 1965 and June, 1967. All treatments were accomplished by "bag dragging" for even distribution to the 3.1 m depth. The chemical costs of the 1967 treatment was $572 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Copper sulfate treatment provided temporary relief from nuisance algal growths. Treatment usually caused a clearing of the waters within 5-10 days. In general, treatment was effective for at least two or three weeks. **REFERENCES**: Frost (pers. comm.).

LAKE NAME: Puddingstone Reservoir
LOCATION: Los Angeles Co., California, USA
SURFACE AREA: 1 km^2
MAXIMUM DEPTH: ---

PROBLEM: Hypolimnetic oxygen depletions and undesirably high surface water temperatures during the summer. Restricted sport fishery. **RESTORATION OBJECTIVE**: To improve the habitat for salmonids. **RESTORATION METHODOLOGY**: An aeration system was installed and operated only during the night. A shore-mounted rotary air compressor rated at 120 l/sec, 7 kg/cm^2 was connected to 370 m of air line, the last 60 m of which was perforated. Operation began in March, 1968 and the compressor ran 12 hrs/night until July. From July through December, the operating schedule was reduced to eight hours. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Aeration resulted in complete destratification, and summer dissolved oxygen levels were increased to about 8 mg/l throughout the water column. The August mean water temperature increased from 22.5° C in 1967 to 25.5°C in 1968. Although the 1968 maximum temperature was less than the 1967 maximum, the minimum temperature in the water column was still greater than the salmonids could tolerate for extended periods and the project was terminated. **REFERENCES**: Fast and St. Amant (1971), Whalls (1968).

LAKE NAME: Rankin Lake
LOCATION: Gastonia, North Carolina, USA
SURFACE AREA: 30 ha
MAXIMUM DEPTH: 3.7 m

PROBLEM: Severe taste, odor, and color problems during vernal and autumnal overturn periods. Used for water supply. **RESTORATION OBJECTIVE**: To improve the water quality and reduce the water treatment costs. **RESTORATION METHODOLOGY**: An aeration system was installed in July, 1970 to maintain destratified conditions. Fourteen hundred meters of perforated, weighted tubing were connected to nine shore-mounted compressors. The capital equipment cost was about $15,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS**: Operation of the system successfully destratified the lake and increased the dissolved oxygen levels to 7-9 mg/l at all depths. Overall water treatment costs decreased about 1.6%. Summer fishkills were reduced but not eliminated. **REFERENCES**: Shuler (1972).

LAKE NAME: Rays Lake
LOCATION: LeSueur Co., Minnesota, USA
SURFACE AREA: 63 ha
MAXIMUM DEPTH: 10 m

PROBLEM: Frequent winterkills due to shallow water and high BOD. **RESTORATION OBJECTIVE**: To improve the winter dissolved oxygen levels thereby preventing fishkills. **RESTORATION METHODOLOGY**: An aeration system was installed, consisting of two parallel 300 m lengths of pipe with perforations at 15 m intervals laid on the lake bottom. Air was supplied by a shore-mounted compressor rated at 47 l/sec. Operation began in January, 1960 and continued until March. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Aeration maintained an ice-free area about 4.5 m in diameter above each point of air release. Only a few holes became large enough to coalesce. Except for the area near the air pipe, the lake remained stratified during aeration. Oxygen levels declined throughout the entire lake during the period of study; even in the open holes, the oxygen concentration was only 0.5 mg/l higher than under the ice (due to mixing with the surrounding water). Areas of the lake with heavy macrophyte growth had the best oxygen conditions throughout the study. **REFERENCES**: Woods (1961).

LAKE NAME: Richland pond
LOCATION: Richland Co., Wisconsin, USA
SURFACE AREA: 2883 m^2
MAXIMUM DEPTH: 4 m

PROBLEM: Overabundant macrophytes, esp. *Myriophyllum exalbescens;* slow growing bluegills *(Lepomis macrochirus)*. **RESTORATION OBJECTIVE**: To limit the macrophyte growth in order to enhance recreational use (e.g., swimming and fishing) of the pond and increase largemouth bass *(Micropterus salmoides)* predation on the small bluegills. **RESTORATION METHODOLOGY**: During the 1973 growing season, the pond was divided in half with plastic sheeting and a light limiting dye (Aquashade) was maintained at a concentration near 0.65 mg/l on one side. The dye, when used at recommended concentrations, costs $50 USA/0.6 hectare-meter of water. Black plastic sheeting was also floated over the pond's surface in a few small test plots at a cost of $70/4000 m^2. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** The black plastic effectively killed the macrophytes in four weeks. Regrowth is being studied. The dye testing included measurements of macrophytes, fish, and water quality; data analyses are underway. **REFERENCES:** Nichols (pers. comm.).

LAKE NAME: Ridge Lake

LOCATION: Coles Co., Illinois, USA
SURFACE AREA: 7.3 ha
MAXIMUM DEPTH: 7.6 m

PROBLEM: Rapid decline of the sport fishery in newly formed lakes. Reservoirs often develop undesirable sport fishery characteristics within 7-8 years after creation; the largemouth bass *(Micropterus salmoides)* fishery disappears, crappies (*Pomoxis* spp.) and bluegills *(Lepomis macrochirus)* become slow-growing; and trashfish species predominate. **RESTORATION OBJECTIVE:** To develop management techniques capable of preventing or improving the aforementioned conditions. **RESTORATION METHODOLOGY:** The lake was formed in 1941. One hundred adult largemouth bass were stocked in May, 1941 and 129 adult bluegills were introduced in June, 1944. Biennially, beginning in 1943, the lake was drained each March and part of the population permanently removed. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** In the years of drainage and culling of the small fish in March, the June bass fry population averaged 54,200; however, in the alternate years the average was only 5900 fry. Carrying capacity of the lake for bass was about 56 kg/ha but when the bluegill population was allowed to expand to 217 kg/ha the bass population was lowered to 35.3 kg/ha. Invading undesirable species such as carp *(Cyprinus carpio)* and buffalo (*Ictiobus* spp.) were removed before resident populations could develop. The angler harvest of largemouth bass was maintained at satisfactory levels through the study period, 1941-51; and the highest catches were made in years when drainage and small fish removal preceded the fishing season. **REFERENCES:** Bennett (1950, 1954).

LAKE NAME: Road Canyon Reservoir

LOCATION: Hinsdale Co., Colorado, USA
SURFACE AREA: 57 ha
MAXIMUM DEPTH: 6 m

PROBLEM: Periodic winterkills. Previous attempts to improve the winter dissolved oxygen conditions met with varying degrees of failure; these included: 1) spreading coal dust on the ice surface, 2) operating outboard motors through holes in the ice, 3) operating a tractor-powered water pump, and 4) increasing the water supply by draining a small upstream reservoir. **RESTORATION OBJECTIVE:** To prevent winterkills. **RESTORATION METHODOLOGY:** An aeration system was installed and operated during the winters of 1966–1969. In 1970 the first system was replaced with one consisting of six perforated tubes anchored on the reservoir bottom, each connected to a shore-based compressor. During the winter of 1971-1972, the second system was replaced with two 2.75 m long "Helixors". The cost for each of the last two systems was about $3500 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Winterkills occurred every year during the operation of the first system. The effect of the second system was uncertain. Although the reservoir did not winterkill, dissolved oxygen concentrations were not significantly improved. In addition, the six compressors required an abnormal amount of attention to keep them running. Preliminary results in mid-March, 1972 (during the "Helixor" operation) indicate that dissolved oxygen concentrations were at the highest levels ever encountered for that time of year; however, the data is still being evaluated. **REFERENCES:** Babcock (pers. comm.), Babcock (1972).

LAKE NAME: Lake Roberts

LOCATION: Silver City, New Mexico, USA
SURFACE AREA: 28 ha
MAXIMUM DEPTH: 9.1 m

PROBLEM: Hypolimnetic oxygen depletion during the summer; high surface temperatures limiting the salmonid population. **RESTORATION OBJECTIVE:** To study aeration and destratification as a management tool in salmonid lakes. To alleviate the stress conditions. **RESTORATION METHODOLOGY:** An aeration system was installed, consisting of a 24 m manifold with 16 equally spaced ceramic diffusers. The manifold was placed in 9 m of water and was held 0.8 m off the bottom. Air was supplied with a diesel-powered compressor at 47 l/sec for seven days in June, 1969. During July and August, 1969 the length of the manifold was reduced to 6 m and air was supplied at 25 l/sec. During both phases of the test, the aerator operated continuously 24 hrs/day. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Within three days the lake was destratified and the dissolved oxygen levels increased to 6 mg/l or higher. The temperature of the entire lake increased to the pre-aeration temperature of the epilimnion. Algal concentrations increased to nuisance bloom proportions during the first phase of the test. Restratification was allowed to occur after seven days of aeration, but algae continued to form thick blue-green mats. Aeration was commenced again after about 20 days; a temporary increase in dissolved oxygen was followed by a gradual decline. Continuous aeration could not satisfy the oxygen demand exerted by the decomposing algae. After approximately one month, the dissolved oxygen levels began to improve. Ammonia nitrogen and total nitrogen concentrations declined during aeration. Orthophosphate and total phosphate concentrations declined during the first phase of aeration but increased during the initial stages of the second phase. Similar patterns were observed for manganese. Aeration resulted in a large increase in salmonid habitat as observed by the horizontal and vertical redistribution of fish, but temperatures were increased to near the lethal limit. **REFERENCES:** Haines (1972), Leach and Harlin, Jr. (1970), McNall (pers. comm.), McNall (1971), Patterson (pers. comm.).

LAKE NAME: Lake Rockwell

LOCATION: Portage Co., Ohio, USA
SURFACE AREA: 3.1 km^2
MAXIMUM DEPTH: 7.6 m

PROBLEM: Nuisance algal blooms. **RESTORATION OBJECTIVE:** To determine the effects of copper sulfate treatment on water chemistry and the plankton community. **RESTORATION METHODOLOGY:** In summer, 1969 a total of 10.24 metric tons of copper sulfate were applied to various areas of the lake; several treatments were involved. **RESULTS (OR STATUS FOR ONGOING PROJECTS):** Treatment was ineffective in controlling the algal population except for a short period in August when both numbers and the rate of photosynthesis were reduced. The zooplankton abundance also decreased in August but was otherwise unrelated to algal abundance or algicide treatment. The copper content of the sediments did not increase. The lack of response to treatment was attributed to the application of insufficient amounts of copper sulfate. **REFERENCES:** Page (1971).

LAKE NAME: Rossmoor Sanitation Dam No. 1
LOCATION: Orange Co., California, USA
SURFACE AREA: 1.5 ha
MAXIMUM DEPTH: 9.5 m

PROBLEM: Severe blue-green algal blooms; summer fishkills; and high chlorine demands for water treatment. Recipient of wastewater treatment plant effluent prior to irrigation usage. **RESTORATION OBJECTIVE**: To control the algal blooms thereby decreasing the chlorine demand and maintaining high dissolved oxygen levels. **RESTORATION METHODOLOGY**: An aeration system was installed at a cost of $3,225 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Operation of the system eliminated stratification and satisfactorily controlled algal populations. Adequate dissolved oxygen levels and a reduced chlorine demand were attained. **REFERENCES**: Sturgeon (pers. comm.).

LAKE NAME: Rubberthread Pond
LOCATION: Easthampden, Massachusetts, USA
SURFACE AREA: 1.6 ha
MAXIMUM DEPTH: 3.1 m

PROBLEM: Excessive growth of duckweed *(Lemna)*. The pond is covered completely. **RESTORATION OBJECTIVE**: To eliminate the nuisance growths of duckweed. **RESTORATION METHODOLOGY**: The duckweed will be harvested mechanically using an oil boom and skimmer. Restoration plans also include artificial aeration of the pond. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not available; the plans have not yet been implemented. **REFERENCES**: Carranza and Walsh (1972), Walsh and Carranza (pers. comm.).

LAKE NAME: Russell
LOCATION: Habersham Co., Georgia, USA
SURFACE AREA: 42 ha
MAXIMUM DEPTH: 12 m

PROBLEM: Hypolimnetic oxygen depletion. A significant part of the lake was unavailable to the fish population. **RESTORATION OBJECTIVE**: To improve the sport fishery. To evaluate the effect of bottom water discharge on the limnology of the reservoir. **RESTORATION METHODOLOGY**: Bottom water was discharged for two years. Measurements were made of temperature, dissolved oxygen, pH, conductivity, alkalinity, hardness, transparency, 14 trace elements, plankton, macrophytes, aufwuchs, benthos, and fish populations and biomass in different parts of the lake and at different depths and seasons. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Bottom water discharge eliminated the intense thermal and chemical stratification that occurred during top water discharge; however, during the summer, thermal and chemical gradients did occur and the bottom waters contained high CO_2 and H_2S concentrations with no DO. Turbidity was reduced. Aufwuchs biomass was increased at depths below the usual thermocline. Macrophytes, benthos, and fish populations and biomass showed no distinct differences between the two discharge regimes. Analysis of the plankton data is not yet complete. **REFERENCES**: Busbee (1969), Duever (pers. comm.; two publications are near completion).

LAKE NAME: Sallie
LOCATION: Becker Co., Minnesota, USA
SURFACE AREA: 4.9 km^2
MAXIMUM DEPTH: 17 m

PROBLEM: Blue-green algal blooms; overabundant macrophytes; diurnal oxygen depletion; and occasional fishkills. Eutrophic conditions stem from the influx of secondary sewage treatment effluent. **RESTORATION OBJECTIVE**: To determine if the full-scale harvest of macrophytes could reduce substantially the nutrient content of the lake. **RESTORATION METHODOLOGY**: Full-scale harvest of macrophytes began in late June, 1970 and continued (8 hrs/day) until 30 September. Approximately one-third of the lake's surface area (littoral zone) was cut over repeatedly. Phosphorus and nitrogen removal in the form of macrophytes and fish were compared to the input of these nutrients based on a detailed nutrient budget. Planning has also been completed for nutrient removal from the wastewater effluent entering the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Harvest of 428.5 metric tons (wet weight) of macrophytes removed only 99.5 kg of phosphorus and 715.5 kg of nitrogen. Fish harvest removed almost three times as much phosphorus and twice as much nitrogen. Macrophyte harvest removed only 1.03% of the phosphorus which entered the lake. **REFERENCES**: Neel (pers. comm.), Neel et al. (1973), Peterson (pers. comm.), Peterson et al. (1973), Rogstad (pers. comm.).

LAKE NAME: Sammamish
LOCATION: King Co., Washington, USA
SURFACE AREA: 19.8 km^2
MAXIMUM DEPTH: 32 m

PROBLEM: Nuisance algal blooms; severe hypolimnetic oxygen depletion in late summer. Rapid eutrophication thought due to the influx of sewage treatment plant effluent. **RESTORATION OBJECTIVE**: To reduce the loading rate for N and P thereby limiting phytoplankton production and ameliorating the associated problems. **RESTORATION METHODOLOGY**: The sewage treatment plant effluents were diverted from the lake. Sewerage collection was provided to the west side of the lake. The east side still depends on septic tank treatment. The project cost $3,000,000 USA and was completed in September, 1968. The loading was reduced by 50–65% for P and 20% for N. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The hydraulic residence time is 3.8 years. Winter maxima of total P have decreased in proportion to the amount diverted, but concentrations during important algal growing periods (spring and summer) have not dropped significantly. Algal standing crops and productivity have remained at pre-diversion levels; however, diatoms are approaching dominance, resulting in a reduced relative abundance for blue-greens. Limnological studies are continuing, including investigation of sediment-water exchange reactions. **REFERENCES**: Emery (pers. comm.), Emery (1972), Emery et al, (1971, 1972, 1973), Horton (1972), Issac et al. (1966), Moon (1972), Rock and Welch (pers. comm.), Welch and Spyridakis (1972), Welch et al. (1972b).

LAKE NAME: San Carlos Lake
LOCATION: Graham Co., Arizona, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundant trashfish, especially carp *(Cyprinus carpio)*. Poor quality sport fishery. **RESTORATION OBJECTIVE**: To evaluate the effect of a piscicide. To restore the fish population balance within the lake. **RESTORATION METHODOLOGY**: During May-July, 1953 toxaphene was applied in nine spot treatments. The areas were selected on the basis of an observed abundance of carp. The areas ranged in size from 6.17×10^2 to 6.17×10^3 m^3 and the concentrations varied from 1.0 to 4.5 mg/l. Application was done by spraying and/or dusting. **RESULTS (OR STATUS FOR ONGOING**

PROJECTS): The areas were not cordoned off and water currents caused a rapid dispersion of the toxicant; after three of the "spot" treatments, much of the lake became toxic. Fish began to be affected within nine to 13 hours; gamefish species succumbed before the carp. Toxaphene was therefore labelled a questionable toxicant for selective treatment of trashfish unless they were somehow isolated from the desirable species. The dead fish were composed of 65% (by weight) carp, approximately 4.5 x 10^5 kg. By August, 1953 the lake turbidity had decreased significantly. **REFERENCES**: Killian (1953).

LAKE NAME: Sebasticook
LOCATION: Newport, Maine, USA
SURFACE AREA: 17.4 km^2
MAXIMUM DEPTH: 17.7 m

PROBLEM: Excessive algal growths. **RESTORATION OBJECTIVE**: To reduce the nutrient loading. **RESTORATION METHODOLOGY**: An advanced facility was constructed for treatment of municipal wastewaters. The major industrial source of phosphorus (75%) was destroyed by fire. Dredging has been recommended. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Limnological investigations were conducted prior to reduction of the nutrient load; however, follow-up studies to determine the impact on lake and algal growths have not yet been made. **REFERENCES**: Keup (pers. comm.; publications are available), Technical Advisory and Investigations Activities, Technical Services Program (1966).

LAKE NAME: Section Four Lake
LOCATION: Cheboygan Co., Michigan, USA
SURFACE AREA: 2.4 ha
MAXIMUM DEPTH: 28 m

PROBLEM: Insufficient information available to reliably predict the response of an oligotrophic lake to artificial aeration/circulation. **RESTORATION OBJECTIVE**: To study the effects of continuous summertime destratification on the heat budget and biota. **RESTORATION METHODOLOGY**: Compressed air was released from a 19 m length of 3.8 cm I.D. perforated plastic tubing anchored in the deepest part of the lake. The perforated tubing was connected to a shore-based diesel-powered compressor rated at 29 l/sec, 7.2 kg/cm^2. The compressor was operated daily for about five hours from mid-June to early September, 1970. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Prior to aeration, temperatures ranged from 21° C at the surface to 5.5° C at the bottom. Within four days the lake was isothermal with a uniform top to bottom temperature of 14° C. As aeration continued, the temperature of the lake gradually increased, and reached 23.3° C by mid-August. Compared to the previous control year, surface temperatures were not greatly altered, but bottom temperatures were as much as 15° C. higher. Dissolved oxygen concentrations were uniform and bottom concentrations remained above 7.0 mg/l during the entire summer. Primary production potential was relatively low during both the aeration and the control years, although in August, 1970, it was about three times higher than during August, 1969. However, phytoplankton standing crops did not reflect the increase and the average standing crops during aeration were consistently lower than during the control year. Continuous mixing probably prevented the phytoplankton from realizing their full growth potential by circulating them into the deeper, more dimly-lit portions of the lake. Destratification resulted in lower zoobenthos standing crops, probably due to the increased respiration rates caused by high bottom temperatures without a corresponding increase in food supply. Rainbow trout *(Salmo gairdnerii)* were distributed throughout the lake after destratification, but showed a preference for the bottom. Trout concentrated in the rising bubble column, perhaps due to higher food concentrations, but no improvement in growth or general condition resulted from destratification. **REFERENCES**: Fast (1971a).

LAKE NAME: Lake Seminole
LOCATION: Lake Seminole, Georgia, USA
SURFACE AREA: ---
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of macrophytes, especially milfoil *(Myriophyllum spicatum)*. **RESTORATION OBJECTIVE**: To determine the usefulness of three herbicides for macrophyte control. **RESTORATION METHODOLOGY**: Paraquat and diquat were applied in a liquid formulation and 2,4-DBEE was applied on clay granules. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Milfoil was controlled using paraquat and a combination of paraquat and diquat but not with diquat alone. Reinfestation was, however, prevented for a longer period using 2,4-DBEE. After application the 2,4-DBEE concentration remained high in the water; the herbicide content of the macrophytes and the sediment was highest for paraquat. **REFERENCES**: Daly et al. (1968).

LAKE NAME: Serpent Lake
LOCATION: Crow Wing Co., Minnesota, USA
SURFACE AREA: 4.8 km^2
MAXIMUM DEPTH: ---

PROBLEM: Slow-growing panfish. Overabundance of small fish. **RESTORATION OBJECTIVE**: To determine the value of increased cropping as a means of improving the growth and average size of the panfish. **RESTORATION METHODOLOGY**: In 1956 14 kg/ha of panfish were removed by seining and trapnetting; and the lake was heavily stocked with adult and yearling northern pike, *Esox lucius* (2.2 to 5.6 kg/ha). Subsequent sampling was conducted in 1958. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Mostly bluegills, *Lepomis macrochirus*, (three-year-olds) were removed by netting in 1956. In 1958 there was a large proportion of older fish, primarily five-year-olds. Increased cropping did not appear to effect the bluegill growth rate; there was a slight reduction, but it was attributed to natural variation. **REFERENCES**: Scidmore (1960).

LAKE NAME: Shagawa Lake
LOCATION: St. Louis Co., Minnesota, USA
SURFACE AREA: 9.5 km^2
MAXIMUM DEPTH: 14.6 m

PROBLEM: Cultural eutrophication; aesthetically objectionable blue-green algal blooms. Influx of sewage treatment plant effluent. **RESTORATION OBJECTIVE**: To stop or reverse the eutrophication process. To limit the occurrence of intense algal blooms. **RESTORATION METHODOLOGY**: A tertiary sewage treatment plant was built to remove over 99% of the phosphorus from the municipal wastewaters. The facility cost $2,300,000 USA. The total phosphorus loading of the lake will be cut approximately 70%. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The facility was completed in January, 1973 and is currently undergoing the necessary adjustments for full-scale operation (February, 1973). **REFERENCES**: Brice (pers. comm.), Brice and Powers (1969), Malueg et al. (1973), Megard (1973), Powers et al (1972), Smith (pers. comm.).

LAKE NAME: Shawnee Lake (Pond Lick Lake)
LOCATION: Portsmouth, Ohio, USA
SURFACE AREA: 1.2 ha
MAXIMUM DEPTH: --

PROBLEM: Criminal introduction of endrin and strychnine during June, 1971; massive kill of aquatic organisms. The endrin stratified in the upper 1.5 m of lake water and the strychnine settled to the bottom. Both poisons were retained by the sediments. **RESTORATION OBJECTIVE**: To remove the poison from the water and sediments in order to permit recreational use of the lake. To prevent the possible contamination of downstream water bodies. **RESTORATION METHODOLOGY**: The upper 1.5 m of water was withdrawn using a 11 l/sec pump and filtered with activated carbon and alfalfa hay. The lake was then drained completely and all of the exposed sediments were removed and buried. The project cost $100,000 USA, primarily due to the usage of carbon. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The activated carbon filter was inoperable due to rapid clogging; however, the alfalfa hay worked well. The poisons were successfully contained and removed from the lake; endrin and strychnine levels dropped below detectable limits. The lake was restocked with fish. **REFERENCES**: Howard (pers. comm.; a report is in press), Nye (1972), Ryckman, Edgerley, Tomlinson and Associates, Inc. (1971), Stoltenberg (1972).

LAKE NAME: Sheridan
LOCATION: Black Hills Meridian, South Dakota, USA
SURFACE AREA: 1.5 km^2
MAXIMUM DEPTH: 27.5 m

PROBLEM: Accelerated eutrophication; excessive macrophytes in a high-use recreation reservoir. **RESTORATION OBJECTIVE**: To decrease the N and P concentrations. To reduce the macrophyte growths. **RESTORATION METHODOLOGY**: Bottom waters were discharged during two winter drawdowns. The water level was reduced 2.4 m during 1971–72 and 1.8 m in 1972–73 at a cost of about $80 USA/yr. The technique was used to flush out the nutrients and expose the macrophyte growths. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The outflow concentrations averaged 13.5 mg P/l and 0.45 mg N/l in 1971–72 (two samples) and only 2.9 mg P/l and 0.10 mg N/l in 1972–73 (two samples). Differences in nutrient loading to the lake, however, preclude conclusive findings. Visual observations indicate a reduction in macrophytes. **REFERENCES**: Heide (pers. comm.).

LAKE NAME: Sheridan County State Lake
LOCATION: Studley, Kansas, USA
SURFACE AREA: 35.2 ha
MAXIMUM DEPTH: --

PROBLEM: Overabundance of macrophytes, primarily *Myriophyllum* sp., *Ceratophyllum demersum*, and *Potamogeton pectinatus*. **RESTORATION OBJECTIVE**: To control the macrophytes. To determine the effect of an artificially increased phytoplankton turbidity on the submergents. **RESTORATION METHODOLOGY**: The lake was fertilized with ammonium nitrate and triple-superphosphate in 1967 and 1968 at a cost of $49.20 USA/ha and $32.40/ha, respectively. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: After fertilization *Aphanizomenon* disappeared while *Anabaena* increased. Although blooms were not always maintained at the desired intensity (45.7–61 cm, Secchi disk), the macrophyte growths were reduced and limited to depths of 1.8 m or less. Light exclusion was ineffective in the shallow areas and herbicides may have to be used for macrophyte control. **REFERENCES**: Cole and Ebert (1968), Schryer et al. (1969).

LAKE NAME: Skaneateles Lake
LOCATION: Onondaga, Cortland and Cayuga Cos., New York, USA
SURFACE AREA: 35.9 km^2
MAXIMUM DEPTH: 90.5 m

PROBLEM: Occasional blooms of phytoplankton during the summer. The lake is now oligotrophic. **RESTORATION OBJECTIVE**: To determine the effects of reducing the phosphorus input. **RESTORATION METHODOLOGY**: In June, 1973 the usage of phosphorus detergents will be banned. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Several limnological parameters are under study. The lake is known to be phosphorus limited. **REFERENCES**: Child and Oglesby (1970), Child et al. (1971), Oglesby (pers. comm.)

LAKE NAME: Skatutakee Lake
LOCATION: Chesire Co., New Hampshire, USA
SURFACE AREA: 70 ha
MAXIMUM DEPTH: 5.2 m

PROBLEM: Nuisance blooms of blue-green algae. Induced by the influx of sewage treatment plant effluent and the entrance of mill wastes via the inflowing river. **RESTORATION OBJECTIVE**: To control the nuisance algal growths. **RESTORATION METHODOLOGY**: The lake was treated with 527 kg of copper sulfate in June, 1968; 545 kg in June, 1969; 545 kg in July, 1970; and 545 kg in September, 1970. The algicide was applied evenly to the 3.1 m depth by "bag dragging". A concentration of about 0.25 mg/l was produced by each application. The chemical costs for each 1970 treatment was $302 USA. The input of mill wastes was halted through a closing of the industry. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Copper sulfate treatments provided temporary improvement in the water quality. Nuisance blooms have not recurred since the mill industry closed. **REFERENCES**: Frost (pers. comm.).

LAKE NAME: Slocum Lake
LOCATION: Lake Co., Illinois, USA
SURFACE AREA: 91 ha
MAXIMUM DEPTH: 2.7 m

PROBLEM: Overabundant carp *(Cyprinus carpio)* population. **RESTORATION OBJECTIVE**: To test the value of baiting carp with corn as a method of concentrating these fish for easier removal. To selectively remove these fish at minimal cost. **RESTORATION METHODOLOGY**: Corn was broadcoast from a boat in a specific area of the lake for 1/2 to 2-1/2 weeks during July-August, 1956 and 1957 (two periods each year). The area was then cordoned off with a tarpaulin and treated with rotenone. The corn was presoaked in two of the trials and the number of applications and weight used ranged from 1 to 9 and 152.5 to 590 kg, respectively. Emulsifiable rotenone (Pro-NoxFish) was used each time at 1 mg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 37.8 kg/ha were removed each year. Carp predominated among the dead fish with much lower weights of Ictalurids also involved. Few gamefish were killed. The drawing range appeared to be very limited but little current was present through the baited area. Treatment could be repeated successfully at short intervals but several treatments in widely separated areas would be required for adequate control. **REFERENCES**: Buck et al. (1960).

LAKE NAME: Smith Mountain Lake

LOCATION: Franklin and Bedford Cos., Virginia, USA

SURFACE AREA: 81 km^2

MAXIMUM DEPTH: 61 m

PROBLEM: Algal blooms; periodic fishkills. Induced by storm sewer overflows and the influx of poorly treated (secondary) domestic sewage. Storm water runoff is also causing sedimentation problems. **RESTORATION OBJECTIVE**: To reduce the nutrient loading fromthe upstream sewage treatment plant. **RESTORATION METHODOLOGY**: A new treatment plant will be installed by 1975 (tertiary treatment). An upstream reservoir may also be utilized as a sink for the sediment load (proposal only). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A limnological survey was begun in August, 1971 and is still in progress. This survey includes primary productivity, chlorophyll, nutrients, light penetration, and dissolved oxygen studies. **REFERENCES**: Hendricks (pers. comm.), Jensen (pers. comm.).

LAKE NAME: Snake Lake

LOCATION: Vilas Co., Wisconsin, USA

SURFACE AREA: 5 ha

MAXIMUM DEPTH: 5.5 m

PROBLEM: DO depletion; nuisance growths of vegetation; and recurring winterkills. **RESTORATION OBJECTIVE**: To alleviate the conditions. **RESTORATION METHODOLOGY**: Nutrient-rich waters were pumped from the lake to a nearby land disposal area, permitting dilution of the remaining waters with low-nutrient influent ground waters. Pumping removed about two-thirds volume in October, 1969 and three volumes during July-August, 1970. In 1972, aluminum (III) was applied to the lake for phosphorus inactivation/precipitation and bottom sealing. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During pumping the lake level temporarily declined about 3.4 m; this resulted in a beneficial deepening of the littoral zone due to dewatering and sediment consolidation. Severe DO depletion continued during the two winters following pumping. The soluble P concentration was significantly diluted and has remained so for two years (total P levels are still relatively high). Nitrogen, chloride, conductance, and color levels were temporarily reduced, but returned to pre-pumping concentrations within one year. Nuisance blooms of *Lemna* (duckweed) were eliminated. The study demonstrated that rapid pumping of some small lakes is technically feasible; and lab experimentation indicated that this renewal technique will be more effective in lakes with less nutrient-rich sediments. Prior to the aluminum treatment, total P concentrations were 0.2 to 0.5 mg/l; during the subsequent year, the level ranged from 0.02 to 0.07 mg/l. Dissolved oxygen conditions during the winter following treatment were noticeably improved. Studies are continuing. **REFERENCES**: Born et al. (1973a), Peterson (pers. comm.; a report is in preparation), Smith (pers. comm.), Smith (undated).

LAKE NAME: Soda Lake

LOCATION: Wyoming, USA

SURFACE AREA: 24 ha

MAXIMUM DEPTH: 12 m

PROBLEM: Danger of winterkills. Used for raising salmonids. **RESTORATION OBJECTIVE**: To prevent winterkill by maintaining adequate dissolved oxygen levels. **RESTORATION METHODOLOGY**: Compressed air was introduced through 670 m of weighted perforated plastic tubing placed in a loop on the lake bottom. Air was supplied by a gasoline-powered compressor rated at 1.6 m^3/min. Aeration began in November, 1958, four days after freeze-up, and continued until the end of April, 1959. The compressor was operated for a period of 632 hrs for an average of about 4 hrs/day. Cost of installation and operation, exclusive of operator's wages, was $950 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In 1958, prior to aeration, the dissolved oxygen concentration during February was 4.9 mg/l at the surface and only a trace below 1.2 m. During the winter of 1958–59, dissolved oxygen levels near the air line ranged from 4.9 mg/l at the surface to 3.2 mg/l at the 9 m depth. Thirty meters away from the air line, dissolved oxygen levels were 3.8 mg/l at the surface and 2.7 mg/l at 6 m. Fish seemed to concentrate in the vicinity of the air line and were in excellent physical condition. **REFERENCES**: Rasmussen (1960).

LAKE NAME: South Rod and Gun Club Lake

LOCATION: Carter Co., Oklahoma, USA

SURFACE AREA: 7 ha

MAXIMUM DEPTH: 5.5 m

PROBLEM: Poor sport fishery. Unbalanced fish population. Slow growth for the sport fish species. **RESTORATION OBJECTIVE**: To determine the effect of fish removal upon the remaining population. **RESTORATION METHODOLOGY**: The lake was partially treated with rotenone on 12 June, 1955 at a concentration of 0.5 mg/l. Black bullhead *(Ictalurus melas)* and bluegill *(Lepomis macrochirus)* were removed by trapping during 1958-60 and 1960, respectively. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 95% of the fish population was removed by chemical treatment. Gizzard shad *(Dorosoma cepedianum)*, carp *(Cyprinus carpio)*, and several other species were completely eliminated from the lake. One year after treatment the total fish standing crop was only one-fifth of pre-treatment levels. The water clarity dropped to 15-20 cm; it previously was 51 cm. The removals during 1958-60 were conducted in an attempt to stimulate growth rates; 101 kg/ha and 54 kg/ha of bullheads and bluegills, respectively were taken from the lake. As a result the growth rate increased for warmouth *(Chaenobryttus gulosus)* but decreased for white crappie *(Pomoxis annularis)* and bluegills. At the end of the study total population numbers were similar to pre-treatment levels, and the weight was still 1/3 lower but increasing. Although the population of harvestable-sized fish was initially reduced by the removal program, in general, the numbers and weights of desirable species of a suitable size increased but not enough to improve the sport fishery. **REFERENCES**: Houser and Grinstead (1961), Jenkins (1956).

LAKE NAME: Spauldings Pond

LOCATION: Janesville, Wisconsin, USA

SURFACE AREA: 10.9 ha

MAXIMUM DEPTH: -- (mean depth, 3.1 m)

PROBLEM: Continuous heavy bloom of blue-green algae during the summer months. Influx of nutrient-rich drainage waters from the surrounding agricultural lands. **RESTORATION OBJECTIVE**: To reduce the algal blooms with 2,3-dichloronapthoquinone (2,3-CNQ). **RESTORATION METHODOLOGY**: 2,3-dichloronapthoquinone (50% active ingredient with wetting agent and 50% water) was sprayed from a boat at a fairly constant flow rate of about

22.7 kg/hr. The rates of application varied between 8.2 and 22.7 kg/treatment, corresponding to concentrations of 20-55 µg/l. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Applications of 30-50 µg/l were effective in eliminating even very heavy blooms of blue-green algae. Abundant populations of fish and zooplankton were unaffected by the treatments. Short-term laboratory experiments indicated that the chemical, in the concentrations necessary to kill blue-green algae, was non-toxic to fish, snails, and macrophytes. **REFERENCES**: Fitzgerald and Skoog (1954).

LAKE NAME: Spring Lake
LOCATION: Ogemaw Co., Michigan, USA
SURFACE AREA: 29 ha
MAXIMUM DEPTH: 5.5 m

PROBLEM: Shallow, eutrophic lake; overabundance of vegetation; frequent winterkills. **RESTORATION OBJECTIVE**: To determine the value of using aeration to prevent winterkill. **RESTORATION METHODOLOGY**: A 76 m length of perforated hose was laid across one end of the lake in water about 1.5 m deep. Air was supplied continuously at 19-24 l/sec for 28 days during March, 1958 with a shore-based compressor. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Before aeration dissolved oxygen concentrations in the vicinity of the system ranged from 0.0 to 1.1 mg/l. The aerator opened up a channel along the entire length of the tube, but the maximum observed dissolved oxygen concentration in the open water was only 1.8 mg/l. A late March thaw resulted in a general increase in the dissolved oxygen concentration of the entire lake, but the open water in the vicinity of the aerator was the last to be affected. **REFERENCES**: Patriarche (1961).

LAKE NAME: St. Olaf Lake
LOCATION: Waseca Co., Minnesota, USA
SURFACE AREA: 41.3 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundant trashfish population. **RESTORATION OBJECTIVE**: To determine the effect of removal on the trashfish and gamefish populations. **RESTORATION METHODOLOGY**: Removal by seining occurred in the winter of 1956-57. Carp *(Cyprinus carpio)* were the only trashfish removed, 22.3 kg/ha. The gamefish investigation started in the summer of 1955 and ended in 1957. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Adequate time had not elapsed for an estimation of year-class strength following removal, but strong year-classes of bluegill *(Lepomis macrochirus)* and crappie *(Pomoxis* spp.) had originated prior to removal operations. There was no indication of a consistent improvement in growth following removal. The effect of harvesting on the carp population structure was not known due to project termination. **REFERENCES**: Scidmore and Woods (1961).

LAKE NAME: State Rearing Pond
LOCATION: Le Sueur Co., Minnesota, USA
SURFACE AREA: 4000 m^2
MAXIMUM DEPTH: 2.1 m

PROBLEM: Nuisance blue-green algal blooms. **RESTORATION OBJECTIVE**: To inhibit the development of blue-green algae through chemical precipitation of phosphorus. **RESTORATION METHODOLOGY**: The pond was divided into two areas using polyethylene sheeting. The phosphorus content on both sides of the pond was raised to 0.5 mg/l by adding commercial fertilizer. On 27 May, 1971 slurried alum was applied to one side of the pond at a rate of 1350 kg/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The phosphorus concentration on the experimental side was rapidly reduced by 90%. *Aphanizomenon* subsequently bloomed on the control side but not on the experimental side. *Anabaena* bloomed on the experimental side in September. *Chara* and pondweed (*Potamogeton* spp.) were most dense on the experimental side when the pond was drained in September. Walleye *(Stizostedion vitreum)* fingerling production was highest on the experimental side. Effects of the treatment on invertebrate production were inconclusive. **REFERENCES**: Bandow (pers. comm.), Bandow (1972).

LAKE NAME: Steilacoom
LOCATION: Pierce Co., Washington, USA
SURFACE AREA: 1.3 km^2
MAXIMUM DEPTH: 6.7 m

PROBLEM: Excessive blue-green algal growth during the summer. **RESTORATION OBJECTIVE**: To prevent the development of *Anabaena* at the sediment-water interface. **RESTORATION METHODOLOGY**: When *Anabaena* filaments first appeared, endothall was injected at the lake bottom (continuous flow of 24 mg/min.). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment inhibited the growth of *Anabaena;* none were subsequently found during June, July and August. Coccoid green algae were present and possibly contributed to the success by utilizing the available nutrients. **REFERENCES**: Carsner (pers. comm.; a report is available), Millenbach (pers. comm.).

LAKE NAME: Stockade Lake
LOCATION: Custer Co., South Dakota, USA
SURFACE AREA: 53 ha
MAXIMUM DEPTH: 13 m

PROBLEM: Low hypolimnetic dissolved oxygen concentrations, high surface temperatures; dense algal blooms; and deteriorating sport fishery. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen levels in the bottom waters. To control algal growths. **RESTORATION METHODOLOGY**: An aeration system was installed in 1967, consisting of 16 diffuser stones mounted on a metal frame. Air was supplied with a gasoline-engine powered compressor rated at 59 l/sec. The aerator was operated intermittently during the summer of 1967 and again in 1968. Operating expenses were about $0.75 USA/hr. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The aerator transferred about 18,000 m^3 of water/hr from the bottom of the lake to the surface. Dye tests indicated that the upwelling water spread laterally away from the central boil for a distance of about 14 m and then sank to a depth of about 4.6 m. At this depth the water spread throughout the lake. Complete destratification was never achieved due to the short periods of operation, and dissolved oxygen concentrations in the profundal regions never reached levels sufficient to support fish life. **REFERENCES**: Van Ray (pers. comm.), Van Ray (1968).

LAKE NAME: Stone Lake
LOCATION: Cass Co., Michigan, USA
SURFACE AREA: 61 ha
MAXIMUM DEPTH: 18.3 m

PROBLEM: Nuisance blue-green algal blooms; overabundance of macrophytes; and high phosphate concentrations in the water and sediments. The high nutrient levels were caused by the influx of sewage plant effluent (secondary treatment) during 1939-65. **RESTORATION OBJECTIVE**: To limit the algal and macrophyte growths by reducing the phosphorus concentration in the water and controlling the release of nutrients from the sediments. **RESTORATION METHODOLOGY**: The inflow of treatment plant effluent was stopped in 1965. A proposed treatment for the summer of 1974 involves phosphate precipitation and settling by addition of fly ash and lime. Concurrently the bottom sediments will be sealed to stop the release of nutrients. The estimated treatment costs will be $2470 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Laboratory and field testing have produced a successful application technique. Various chemical and biological studies are underway in two 0.4 ha ponds. **REFERENCES**: Cratty (pers. comm.; several reports are available), Tenney (pers. comm.), Tenney (1972), Tenney and Echelberger, Jr. (1970), Tenney et al. (1972), Verhoff et al. (1971).

LAKE NAME: Stone Valley Reservoir
LOCATION: Huntingdon Co., Pennsylvania, USA
SURFACE AREA: 29 ha
MAXIMUM DEPTH: 9.8 m

PROBLEM: Limited recreational usage due to overabundant macrophytes. **RESTORATION OBJECTIVE**: To control the macrophytes in order to alleviate the interference with boating. To provide optimal fish habitat. **RESTORATION METHODOLOGY**: The proposed project includes: 1) mechanical harvesting wherever possible, and 2) chemical treatment in the shallow bays (estimated cost of $40,000 USA for three years). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Some preliminary studies are underway, but the treatment measures have not yet been implemented. **REFERENCES**: Arnold (pers. comm.).

LAKE NAME: Storm Lake
LOCATION: Buena Vista Co., Iowa, USA
SURFACE AREA: 12.4 km^2
MAXIMUM DEPTH: 1.8 m

PROBLEM: Nuisance algal blooms. **RESTORATION OBJECTIVE**: To control the blue-green algae with copper sulfate. **RESTORATION METHODOLOGY**: The algicide was applied by boat at a carefully controlled dosage of 0.5 mg/l for the 1.8 m depth and 1 mg/l for the upper 0.9 m. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Actual before and after counts indicated that the blue-greens were almost completely eradicated in the zones of treatment. As a result the beaches were usable all summer. There were no losses of livestock or wildlife during the year. **REFERENCES**: Rose (1954).

LAKE NAME: Sunshine Springs
LOCATION: Langlade Co., Wisconsin, USA
SURFACE AREA: 4000 m^2
MAXIMUM DEPTH: 1 m (before deepening)

PROBLEM: Excessive accumulation of sediment; heavy growths of *Chara;* and restricted sport fishery. **RESTORATION OBJECTIVE**: To remove the bottom sediments thereby benefiting the brook trout *(Salvelinus fontinalis)* population. **RESTORATION METHODOLOGY**: A hydraulic cutterhead dredge was used to deepen the pond to a maximum depth of 3.7 m. About 5,400 m^3 of sediments were removed at a total cost of $11,224 USA ($2.07/m^3). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: As a result of dredging, the ingress of groundwater increased by 40% and the annual summer emigrations of trout were reduced. Populations of 0- and 1-year trout increased by about 50% after dredging. Over 95% of the benthic invertebrates were removed by the dredge, but after 24 months, the benthos had increased to 49% of the previous levels. Oligochaeta made up most of the benthos increase; and Chironomidae, Amphidoda, and Hirudinae showed only minor increases. Dense populations of *Daphnia ambigua* developed the second year after dredging; they had previously been absent. The effects of dredging are still being monitored. **REFERENCES**: Carline (pers. comm.).

LAKE NAME: Suttle Lake
LOCATION: Oregon, USA
SURFACE AREA: 1.1 km^2
MAXIMUM DEPTH: 21 m

PROBLEM: Rapidly increasing eutrophication; dense algal blooms. **RESTORATION OBJECTIVE**: To halt or reverse the eutrophication process. **RESTORATION METHODOLOGY**: A phosphate inactivation/precipitation experiment is being considered for this lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Some preliminary studies are underway, but treatment plans have not yet been formalized. **REFERENCES**: McHugh (pers. comm.).

LAKE NAME: Lake Tahoe
LOCATION: California and Nevada, USA
SURFACE AREA: 499 km^2
MAXIMUM DEPTH: 503 m

PROBLEM: Increasing signs of eutrophication. Increased growths of periphyton and phytoplankton around the shoreline; and decreased water clarity. Caused by the influx of treatment plant effluent and poor land use practices in the drainage basin. **RESTORATION OBJECTIVE**: To reduce the nutrient input and the man-induced siltation. To protect the oligotrophic condition of the lake. **RESTORATION METHODOLOGY**: Restoration/protection measures include tertiary treatment of the domestic wastewaters and diversion of the effluent out of the drainage basin (initially the effluent was sprayed upon the land, but results were unsatisfactory). The system began operation in 1968 at a total cost of $28,000,000 USA. In addition, soil erosion is being limited by making the developers and planners aware of the consequences of poor land practices and by enforcing regulations intended to minimize soil loss during urbanization of the area. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The hydraulic residence time is about 700 yrs. The nutrient sources have been identified and their algal growth potential determined. In-lake algal growth is presently N limited but reduced P and continued N inputs are expected to result in P limitation in the future. Studies are in progress. **REFERENCES**: Division of Soil Conservation, Department of Conservation (1969), Glancy (pers. comm.), Glancy (1969, 1971), Goldman (pers. comm.), Goldman (1970, 1972a and b), Goldman et al. (1970), Johnson (pers. comm.), Lake Tahoe Area Council (1970), Mathews and Schwary (1969), Richards (pers. comm.).

LAKE NAME: Tahoe Keys
LOCATION: South Lake Tahoe, California, USA
SURFACE AREA: 55 ha
MAXIMUM DEPTH: 7.6 m

PROBLEM: Water quality deterioration due to urbanization in the drainage basin. Siltation and eutrophication must be prevented in order to protect an adjacent oligotrophic lake

(Lake Tahoe). **RESTORATION OBJECTIVE**: To maintain a high water quality and to increase the water clarity. **RESTORATION METHODOLOGY**: Nutrients are restricted by: 1) macrophyte cutting and removal, 2) controlling the drainage into the lake, 3) community education, and 4) water circulation combined with precipitation of phosphate, algae, and suspended materials. The system involved typical water treatment with an upflow solid contact clarifier using alum and polymers (10 MGD with 40 MGD circulation). **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: 1972 was the first year of operation. Water clarity increased from 1.5 to 2.1 m and phytoplankton blooms were prevented on two occasions. **REFERENCES**: Favreau (pers. comm.), Moellmer (pers. comm.), Moellmer and Ung (1972).

LAKE NAME: Talquin

LOCATION: Gadsden and Leon Cos., Florida, USA
SURFACE AREA: 43.7 km^2
MAXIMUM DEPTH: 15 m

PROBLEM: Eutrophic impoundment. Nuisance algal blooms; overabundance of water hyacinths *(Eichornia crassipes)*; summer dissolved oxygen depletion; and a declining sport fishery. Induced by agricultural runoff. **RESTORATION OBJECTIVE**: To limit the primary production and to reverse the sport fishery decline. **RESTORATION METHODOLOGY**: A drawdown will be implemented in winter, 1973-74 to permit stabilization and oxidation of the organic-rich bottom sediments. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Two years of pre-drawdown water quality and phytoplankton productivity data are available; the kinetics of sediment oxidation, dewatering, and phosphate release will be studied during drawdown. A trial drawdown in winter, 1972-73 yielded encouraging results. **REFERENCES**: Harriss (pers. comm.; reports are available).

LAKE NAME: Taneycomo

LOCATION: Missouri, USA
SURFACE AREA: 210 km^2
MAXIMUM DEPTH: 70 m

PROBLEM: Influx of nutrient-rich, low DO water from an upstream reservoir (Table Rock). Acute danger of fishkills. Excessive growths of vegetation. **RESTORATION OBJECTIVE**: To control the vegetation abundance. To increase the dissolved oxygen content of the inflow. **RESTORATION METHODOLOGY**: Four methods of aerating the Table Rock discharge were tried: 1) oxygenated water from the epilimnion was spilled over the top of the dam and allowed to mix with the turbine discharge, 2) the turbines were operated at less than half capacity; air was drawn into the turbines through vent tubes and mixed with the discharge waters, 3) two large, six-armed diffusers were lowered into the reservoir to a depth of 56.5 m immediately upstream from the outlet. These were supplied with compressed air at the rate of 34 m^3/min from two large, gasoline-powered compressors, and 4) air (255 m^3/min from 10 compressors) was pumped into the turbine chambers while operating at full capacity. Cost of construction of diffusers, installation of necessary air lines, rental of compressors, and operating expenses for one season were about $300,000 USA. Various chemical and physical methods were also studied for control of the vegetation. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: As a result of the first method, the DO levels were effectively increased, but the water temperature became undesirably high for downstream salmonid populations and, of course, the spilled water was unavailable for power production. Operation of the turbines at 40% capacity also permitted the maintenance of high DO concentrations, but at times, full capacity was needed. The air diffusers were quite effective in increasing the oxygen content of the water in their immediate vicinity and above. The volume of water affected, however, was much less than went through the penstocks when the turbines were operating at full capacity. The fourth method maintained high DO levels when only one or two turbines were operating but not with all four. Studies of these aeration alternatives are continuing. The vegetation control studies concluded that the widespread use of herbicides would not be generally effective; would be very costly; and would endanger the fish, fish food organisms, and other aquatic life, both in the reservoir and downstream. An underwater cutter would be very costly; would require an expert operator; and could not be operated effectively. Short-lived herbicides will probably be used locally to clear boat lanes, etc. where needed. **REFERENCES**: Fry and Hanson (1968), Funk (pers. comm.), U.S. Army, Corps of Engineers, Little Rock District (1972), Walker and Fry (undated), Water Spectrum (1972).

LAKE NAME: Tennessee Valley Authority reservoirs

LOCATION: Alabama, North Carolina, and Tennessee, USA
SURFACE AREA: --
MAXIMUM DEPTH: --

PROBLEM: Overabundance of macrophytes, esp. milfoil *(Myriophyllum spicatum)* and *Najas* spp. **RESTORATION OBJECTIVE**: To control the macrophytes in order to enhance water resources development and limit the breeding habitat of the mosquito, *Anopheles quadrimaculatus* (an important malaria vector). **RESTORATION METHODOLOGY**: Three methods of control were used: 1) flooding, 2) overwinter drawdown, and 3) application of 2,4-D. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Flooding was effective for some species but not for others. Overwinter drawdown, and application of 2,4-D in areas that were not exposed, resulted in some macrophyte-free regions for 4 yrs after treatment. Herbicide application was not detrimental to the benthos population except through elimination of the macrophytes. There was little uptake of 2,4-D by fish but some was taken up by mussels. Significant concentrations of 2,4-D occurred in the sediments for up to 10 months. No adverse effects were noted on the fauna or water quality. **REFERENCES**: Hall et al. (1946), Penfound et al. (1945), Smith and Isom (1967), Smith et al. (1967).

LAKE NAME: Teton Pond

LOCATION: Nebraska, USA
SURFACE AREA: 1 ha
MAXIMUM DEPTH: 3.5 m

PROBLEM: Excessive growths of macrophytes and planktonic algae. **RESTORATION OBJECTIVE**: To reduce the growth of macrophytes and algae. To evaluate a new control technique. **RESTORATION METHODOLOGY**: Columns of water and associated plant growth were isolated in in-situ experimental boxes. These columns were treated with varying concentrations of two textile dyes in order to reduce the total illumination incident to the photic zone. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were completely eliminated in the experimental boxes. There was also a shift in the dominant algae from blue-greens prior to treatment to greens and diatoms after treatment. No deleterious effects were observed; samples from the experimental boxes, when incubated in the pond with C^{14}, still had the ability to fix carbon. Pond water incubated in the reduced light of the experimental boxes showed greatly reduced rates of C^{14} uptake. **REFERENCES**: Buglewicz (1972), Hergenrader (pers. comm.).

LAKE NAME: Togus Pond

LOCATION: Augusta, Maine, USA
SURFACE AREA: 2.6 km^2
MAXIMUM DEPTH: 15.4 m

PROBLEM: Culturally eutrophic lake. Nuisance algal blooms; excessive macrophytes; and hypolimnetic oxygen depletion. **RESTORATION OBJECTIVE**: To maintain and restore the recreational and aesthetic potential by controlling algal growth and maintaining high dissolved oxygen levels at all depths. **RESTORATION METHODOLOGY**: Two 0.3 m diameter, 1.5 m long aerators were placed in the deepest part of the lake. Air was supplied by two shore-mounted electrically-powered compressors rated at 10 l/sec, 7 kg/cm^2. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Aeration began in August, 1971, when the lake was thermally and chemically stratified. Anaerobic conditions existed below the 8 m depth and an 18° C temperature difference was observed between the surface and 15 m. Stratification was eliminated after 51 days (the period would have been considerably less if mechanical difficulties had not caused interruptions). Aeration resulted in: 1) slightly greater water clarity, 2) decreased concentrations of iron and manganese near the bottom (slightly increased at the surface), 3) increased dissolved oxygen levels (maintenance of 95% saturation or higher), 4) elimination of H_2S, and 5) decreased CO_2 content of the bottom waters (no increase near the surface). The concentration of orthophosphate increased near the surface but decreased at greater depths with a decline in the total content of the lake water. Destratification caused the phytoplankton to be distributed evenly throughout the water column, but no significant reduction occurred in the surface waters. Blue-green and green algal concentrations remained lower in the aerated basin than in the control basin during the period of study, but diatom populations were high in both basins. Zooplankton levels increased after destratification. **REFERENCES**: Jason M. Cortell and Assoc. (1973), McCann (pers. comm.).

LAKE NAME: Tohopekaliga

LOCATION: Osceola Co., Florida, USA
SURFACE AREA: 92 km^2
MAXIMUM DEPTH: 4.6 m (full pool)

PROBLEM: Accumulation of flocculent organic sediments. Degradation of fish habitat. Nuisance algal blooms. Lack of macrophytes. Encroachment by agricultural and urban development. These problems were a direct result of water level stabilization in 1964; the historic natural range of water level fluctuation was reduced by about 55%. **RESTORATION OBJECTIVE**: To improve the conditions by consolidating and stabilizing the bottom sediments. To evaluate the effects of drawdown. **RESTORATION METHODOLOGY**: After preliminary studies and local community acceptance, the lake was artificially lowered during 1970-72. Water levels were dropped 0.9 m between March and June, 1970; remained stable until February, 1971; reached the maximum drawdown by June, 1971; and raised to near normal between August, 1971 and March, 1972. Draining was done by gravity and costs were therefore nominal. Approximately $200,000 USA was spent over a period of four years for monitoring the effects of dewatering on physical, chemical, and biological parameters. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Compaction or loss (due to wind erosion or complete oxidation) of organic sediments ranged from 55 to 100%. The thickness of organic materials at 10 sampling stations varied from about 3 to 15 cm prior to drawdown and from 0 to 10 cm after drawdown. The sediments either disappeared completely or became a compacted, peat-like material. In all areas the substrate became firm and solid and, except in those areas which were not completely dried, remained solid after refilling–only slight expansion occurred. Although reductions in the concentrations of ammonia, organic nitrogen, and volatile solids in the sediments were expected, error in laboratory procedures tended to obscure the results. An inconsistent reduction in ammonia content was noted. A 24 hr carbon dioxide evolution test carried out on the exposed sediments showed that the drying organic material was releasing considerable amounts of carbon dioxide due to microbial activities. Water quality monitoring before and during drawdown indicated that most dissolved constituents increased in concentration during drawdown. During refilling, reductions occurred and concentrations approached pre-drawdown levels (total phosphorus was lower throughout the lake). Excessive algal production was not reduced by dewatering, although a greater species diversity was observed after refilling. Fish and invertebrate populations doubled in less than a year following drawdown. **REFERENCES**: Holcomb (pers. comm.), Holcomb and Wegener (1971), Pride (pers. comm.), Wegener (pers. comm.), Wegener and Holcomb (1972).

LAKE NAME: Lake Traverse

LOCATION: Minnesota and South Dakota, USA
SURFACE AREA: 44.6 km^2
MAXIMUM DEPTH: 4.9 m (full pool)

PROBLEM: Overabundant population of trashfish, especially carp *(Cyprinus carpio)* and bullheads (*Ictalurus* spp.). **RESTORATION OBJECTIVE**: To limit the trashfish population in order to benefit the gamefish. **RESTORATION METHODOLOGY**: Carp and bullheads were removed by commercial fishermen (under contract) using hoopnets and seines nearly every year, 1945-57. Removal ranged up to 212 kg/ha for carp and 63 kg/ha for bullheads. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The weight of carp per seine haul decreased from 11,757 kg in 1946-47 to 231 kg in 1957-58. The catch of bullheads per hoopnet more than doubled from 1951-52 to 1956-57. The size distribution of the captured carp did not change, indicating continued but low recruitment to the adult population. Before 1953 the average catch of crappies (*Pomoxis* spp.) per seine haul was 400-1000 fish; by 1957-58 the average haul was 84,000 fish. Winterkill, stocking, and water level fluctuations occurred but did not seem to have a dominant influence upon the results. **REFERENCES**: Moyle and Clothier (1959).

LAKE NAME: Trout Lake

LOCATION: Lake Co., Florida, USA
SURFACE AREA: 43 ha
MAXIMUM DEPTH: 3.7 m

PROBLEM: Eutrophic lake. Extensive areas of muck bottom; low benthic fauna populations; limited fish spawning areas; large trashfish population. **RESTORATION OBJECTIVE**: To evaluate the effects of dredging on bottom fauna and fish populations. **RESTORATION METHODOLOGY**: A hydraulic dredge was used to remove muck and increase the area of sandy bottom. About 6.9 ha of lake bottom were dredged and a total of 31,800 m^3 of muck was removed. Dredging cost $27,500 USA ($0.86/m^3). This cost included operational expenses only and did not cover preliminary water and sediment depth surveys or administrative and legal costs. Spoil disposal sites were obtained from local landowners without monetary compensation. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Muck removal was not entirely successful. In some areas, chunks of peaty sediment were dislodged by the dredge and remained on the bottom. In other areas flocculent muck became suspended in the water column and settled out after the dredge had passed. About 2.8 ha of lake bottom were successfully converted from muck to sand. Algal production declined after dredging due to increased turbidity. Initially the benthic populations decreased in all portions of the lake; however, after repopulation, the converted sandy areas showed both greater numbers and diversity of species than the muck areas. Ammonia nitrogen concentrations increased temporarily as a result of dredging, but other chemical parameters exhibited normal variability. No immediate response to dredging by the fish population was evident, either in numbers, species or angler success. **REFERENCES**: Wilbur (pers. comm.), Wilbur (1971), Wilbur and Langford (1972 a and b), Wilbur and May (1970).

LAKE NAME: Turtle Lake

LOCATION: Becker Co., Minnesota, USA
SURFACE AREA: 86.3 ha
MAXIMUM DEPTH: ---

PROBLEM: Slow-growing panfish population. **RESTORATION OBJECTIVE**: To determine the value of removal as a means of improving the growth and average size of the remaining panfish. **RESTORATION METHODOLOGY**: In 1956 23.9 kg/ha of panfish were removed by seining and trapnetting. Subsequent sampling was conducted in 1958. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The fish population was composed of bluegills *(Lepomis macrochirus)*, pumpkinseed *(Lepomis gibbosus)*, green sunfish *(Lepomis cyanellus)*, and hybrids. Trapnetting removed mostly hybrids with bluegill the second most important species. In 1958 the number of hybrids per net left was the same as in 1956, but the number of bluegills increased 15-fold. The bluegills were mostly three-year-olds in 1956. There was no significant change in the rate of growth (perhaps a slight increase). **REFERENCES**: Scidmore (1960).

LAKE NAME: Tuxedo

LOCATION: Orange Co., New York, USA
SURFACE AREA: 1.2 km^2
MAXIMUM DEPTH: 18.3 m

PROBLEM: Nuisance blue-green algal blooms; hypolimnetic oxygen depletion. Used as a supply of drinking water. **RESTORATION OBJECTIVE**: To reduce algal productivity with copper sulfate. To increase DO levels by hypolimnetic aeration. **RESTORATION METHODOLOGY**: Copper sulfate is applied periodically at an approximate cost of $7.40 USA/ha/yr. A hypolimnetic aeration system will probable be installed in the near future. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Algal problems can be controlled but not eliminated by application of copper sulfate. The nutrient levels remain fairly high. **REFERENCES**: Heffner (pers. comm.).

LAKE NAME: Twin lakes (2)

West Twin
East Twin

LOCATION: Kent, Ohio, USA
SURFACE AREA:
West Twin (26 ha)
East Twin (32 ha)
MAXIMUM DEPTH:---

PROBLEM: Nuisance blooms of blue-green algae; extensive macrophyte production; high fecal coliform counts; severe dissolved oxygen depletion; and other indices of excessive eutrophication. **RESTORATION OBJECTIVE**: To reduce the production of vegetation by limiting the nutrient input and lowering the in-lake phosphorus concentration. **RESTORATION METHODOLOGY**: Nutrient diversion is nearly complete. In the future phosphorus will be inactivated/precipitated in one of the lakes, leaving the other as a control. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Diversion is about 80% complete (February, 1973). No substantial improvement has been observed in the lakes, other than removal of the fecal coliforms. Experiments with alum and sodium aluminate as nutrient inactivating agents has revealed that aluminum to phosphorus ratios of up to 50:1 might be required and that these agents may have potentially harmful side effects. Monitoring of the effects of diversion, and research with the above agents and with fly ash and clays is continuing. **REFERENCES**: Cooke (pers. comm.), Cooke and Kennedy (1970).

LAKE NAME: Twin Valley Lake

LOCATION: Iowa Co., Wisconsin, USA
SURFACE AREA: 60.8 ha
MAXIMUM DEPTH: 10.7 m

PROBLEM: Influx of nutrient-rich waters. Newly formed reservoirs in this area rapidly develop many of the problems associated with excessive eutrophication. The region is composed primarily of rich, agricultural lands. **RESTORATION OBJECTIVE**: To determine the potential of using continual bottom water discharge to delay or prevent excessive eutrophication. **RESTORATION METHODOLOGY**: The discharge structure was built to permit the continual discharge of water from the bottom of the reservoir. Surface water outflow occurs only at high water levels. The reservoir began operation in May, 1967. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Comparative limnological information was available from a nearby reservoir with similar morphological characteristics but equipped with a surface outlet. Winter DO concentrations were maintained at increased levels near the bottom. Severe DO conditions existed during the summer, similar to conditions measured in the reservoir equipped with a surface water discharge. The volume of water discharged from the bottom during June–August, 1969 equalled 1.8 times the aseptic zone. Increased temperatures occurred in the bottom waters and thermal stratification was reduced. Approximately 25% and 22% more N and P, respectively would have been released by a bottom water discharge versus a surface discharge. Reduced concentrations of total iron, ammonia nitrogen, dissolved phosphorus, and manganese were maintained near the bottom. There was an obnoxious odor near the outlet structure due to the release of gases from the discharge waters. The study ended in 1970 and the biotic evaluations were therefore suggestive rather than conclusive. **REFERENCES**: Dunst (pers. comm.), Wirth et al. (1970).

LAKE NAME: Upper Blue Lake

LOCATION: Lake Co., California, USA
SURFACE AREA: 42.5 ha
MAXIMUM DEPTH: 15.3 to 16.8 m

PROBLEM: Excessive eutrophication. Nuisance algal blooms and overabundant midge population. **RESTORATION OBJECTIVE**: To demonstrate a biological control for the midge and planktonic algal populations. **RESTORATION METHODOLOGY**: Approximately 6000 *Menidia audens* (Mississippi silversides) were stocked in September, 1967. These young-of-the-year were 50-70 m in size. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Sampling during 1968 did not produce any survivors or progeny. The fate of the stocked fish is uncertain. **REFERENCES**: Cook, Jr. and Moore (1970).

LAKE NAME: Upsilon
LOCATION: Rolette Co., North Dakota, USA
SURFACE AREA: ---
MAXIMUM DEPTH: 7.3 m

PROBLEM: Eutrophic lake. Periodic winterkills due to incomplete mixing and low DO content prior to ice cover. **RESTORATION OBJECTIVE**: To improve the dissolved oxygen levels in order to permit overwinter survival of the fish. **RESTORATION METHODOLOGY**: In 1960 an aeration system was installed, consisting of three air compressors, each connected to 305 m of perforated tubing placed in the deepest parts of the lake. This system was operated every winter until 1966, at which time a supplemental system was also installed in the lake. This consisted of a single larger compressor connected to two diffuser stones. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Throughout the 10 year period of study, critical dissolved oxygen levels existed even when both aerators were operating. Winterkill was noted during 1961, 1962, 1964, 1965, 1967, and 1968. Winterkill also occurred after the aerators were removed but not under conditions of fairly light snow and ice cover. **REFERENCES**: Kreil (1969, 1971), Tubb (1966).

LAKE NAME: Vancouver Lake
LOCATION: Clark Co., Washington, USA
SURFACE AREA: 10.5 km^2
MAXIMUM DEPTH:
3.7 m (during floods)
1.2 m (during summer conditions)

PROBLEM: Nuisance blue-green algal blooms; high numbers of coliform bacteria. Highly eutrophic conditions induced by the influx of septic tank effluents, dairy manure wastes, and agricultural and urban land runoff; and by the release of nutrients from the bottom sediments. **RESTORATION OBJECTIVE**: To restore the lake for water contact activities by improving the water quality and limiting the algal growth. To increase the dissolved oxygen levels and control the coliform bacterial counts. **RESTORATION METHODOLOGY**: Hydraulic and water quality model studies suggest: 1) dredging of the lake, 2) introducing better quality water from a nearby river, and 3) curtailment of septic tank effluents, as the measures necessary to increase lake use potential as well as water quality. The lake can be improved to meet class A water quality standards if it is dredged to 3 m below mean sea level and about 19.8 m^3/sec of river water is introduced into the lake. This prediction does not take into account the reduction in pollutional loading to the lake. Cost studies are in progress. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The restoration measures have not yet been implemented. Pre-treatment studies are continuing. **REFERENCES**: Bhagat (pers. comm.; reports are in preparation), Bhagat and Orsborn (1971), Bhagat et al. (1972), Lin et al. (1972), Orsborn (pers. comm.; reports are in preparation).

LAKE NAME: Veterans Memorial Pond
LOCATION: La Crosse Co., Wisconsin, USA
SURFACE AREA: 1.9 ha
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of trashfish, especially carp *(Cyprinus carpio)*. The pond is managed as a put and take salmonid fishery. **RESTORATION OBJECTIVE**: To eliminate the carp population with piscicides. **RESTORATION METHODOLOGY**: Fintrol (antimycin) was applied on 5 October, 1965. Sufficient amounts were added to achieve an average concentration of 10 μg/l of antimycin. A hand-operated seed spreader was used. The inflow was reduced and the water level drawn down before treatment. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Some fish species started dying within two hours. After nine days 499 kg of carp were collected and about 22.7 kg for all other species. As expected, bullhead and catfish *(Ictalurus* spp.) were not killed. The toxicant became sublethal in six days as determined by in-situ fish bioassays. Aquatic insects were also killed, but the waterfowl were apparently unaffected. **REFERENCES**: Berger (1965).

LAKE NAME: Lake Volney
LOCATION: Le Sueur Co., Minnesota, USA
SURFACE AREA: 1 km^2
MAXIMUM DEPTH: 21.4 m

PROBLEM: Overabundant trashfish populations. **RESTORATION OBJECTIVE**: To determine the effect of partial removal on the trashfish and gamefish populations. **RESTORATION METHODOLOGY**: Removal by seining began in the winter of 1953-54 and ended in 1957-58. The weight of trashfish removed varied from 37.2 kg/ha (all carp, *Cyprinus carpio)* in 1957-58 to none in 1954-55. The gamefish investigation began in the summer of 1955 and ended in 1957. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The black crappie *(Pomoxis nigromaculatus)* was the dominant panfish. Year-class strength varied during the period of removal but the fluctuations did not seem to be directly associated with the intensity of removal. There was no indication of a consistent improvement in growth following removal. The length-frequency distribution and average weight of the removed carp indicate that harvesting had no appreciable effect on the carp population structure. **REFERENCES**: Scidmore and Woods (1961).

LAKE NAME: Waccabuc
LOCATION: Westchester Co., New York, USA
SURFACE AREA: 53.6 ha
MAXIMUM DEPTH: 13 m

PROBLEM: Nuisance algal blooms; hypolimnetic oxygen depletion. Septic tank drainage and lawn fertilizer runoff have apparently been responsible for the eutrophic conditions. **RESTORATION OBJECTIVE**: To reduce the algal standing crop by preventing anaerobic nutrient regeneration, increasing nutrient precipitation, and increasing zooplankton grazing. To create suitable habitat for cold-water fish species. **RESTORATION METHODOLOGY**: Two hypolimnetic aerators and compressors were purchased at a total cost of $60,000 USA. A helicopter was used to install the equipment in the lake. Each aerator circulates water at a rate of about 250 l/sec. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Monitoring began in 1972 and aeration began in June, 1973. Preliminary results indicate that the dissolved oxygen content of the water moving through the aerator is increased from zero to 8-10 mg/l. The dissolved oxygen content of the hypolimnion increased from zero to 3.5 mg/l during the first six weeks of operation. **REFERENCES**: Dorr (pers. comm.), Fast (pers. comm.).

LAKE NAME: Waco Reservoir
LOCATION: McLennan Co., Texas, USA
SURFACE AREA: 28 km^2
MAXIMUM DEPTH: 23 m (conservation pool)

PROBLEM: Summer DO depletions in the hypolimnion, resulting in taste and odor problems. Extensive water treatments were necessary prior to domestic usage. **RESTORATION OBJECTIVE**: To eliminate the thermal stratification and improve the bottom water quality. **RESTORATION METHODOLOGY**: An aeration system was installed near the dam in 1967. A 12 m length of 3.1 cm ID perforated plastic tubing was placed on the bottom and supplied with air via a 300 m length of tubing from a gasoling-powered compressor rated at 52 l/sec. In 1968 the tubing was replaced with galvanized steel pipe and in 1970, an electric compressor was installed, rated at 47 l/sec, 7.0 kg/cm^2. The compressor has been operated for one or two 8-hour shifts/day, 5 days/week. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Operation of the system has reduced the maximum top to bottom temperature differential; in 1970 it was about 6° C as compared to 17° C in the year prior to aeration/circulation. Anaerobic conditions have been eliminated in the hypolimnion (D. O. concentrations remained above 25% saturation during the entire summer) and necessary water treatments have been reduced greatly. Alkalinity, pH, and hardness have been unaffected and algae have not increased during system operation. **REFERENCES**: Biederman (pers. comm.), Biederman and Fulton (1971).

LAKE NAME: Wahiawa Reservoir
LOCATION: Hawaii, USA
SURFACE AREA: 20 ha
MAXIMUM DEPTH: 26 m (full pool)

PROBLEM: Danger of fishkill. An extended drawdown coupled with a high rate of algal die-off threatened to create critical dissolved oxygen conditions. **RESTORATION OBJECTIVE**: To prevent a fishkill by increasing the oxygen content of the water. **RESTORATION METHODOLOGY**: A floating aeration system was installed to partially destratify the reservoir in mid-September, 1971. A 40 l/sec gasoline-powered rotary compressor was mounted on a raft and connected to a 25 m long perforated pipe suspended at a depth of 2.7 m. Because of engine noise and maintenance requirements, the system was operated no more than 10 hrs/day. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During the three months preceding aeration, the oxygenated zone gradually declined from 3.6 to less than 2 m. After two days of light rain and cloudy weather on 16 and 17 September, surface dissolved oxygen concentrations were less than 0.5 mg/l and dead fish were noted in parts of the reservoir. The aeration system was put into daily operation and the kill ended by 23 September. The depth of the fish survival zone increased gradually and by the end of October the inhabitable volume of the reservoir was enlarged by about 30%. One-hundred fold increases in zooplankton numbers were observed in the vicinity of the aeration system. Increased inflows resulted in gradually improved conditions during November and the aerator was removed in December. A larger, permanent aeration system to completely destratify the reservoir prior to the critical full drawdown period was recommended. **REFERENCES**: Devick (pers. comm.), Devick (1972).

LAKE NAME: Lake Washington
LOCATION: near Seattle, Washington, USA
SURFACE AREA: 87.6 km^2
MAXIMUM DEPTH: 76.5 m

PROBLEM: Rapid eutrophication due to the influx of secondary-treated sewage plant effluent (represents about 56% of the total P loading). **RESTORATION OBJECTIVE**: To reduce the nutrient input thereby decreasing the algal abundance and improving the water clarity. To prevent further deterioration of the water quality. **RESTORATION METHODOLOGY**: Partial diversion of the sewage plant effluent occurred in 1963; this removed 28% of the effluent. Diversion was completed in 1968. The total cost was near $125,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: In 1962 the colonial blue-green algal species comprised 96% of the phytoplankton biomass; in 1970 the percentage was 83% and the total biomass was only 30% of that in 1963. The summer water clarity increased from 1 m in 1963 to 2.8 m in 1969. After diversion the in-lake limiting nutrient changed to phosphorus; it had previously been nitrogen. During summer, 1963-68 the surface P levels dropped one-fourth; nitrate-nitrogen and CO_2 also decreased but not as much. In summer, 1963 the hypolimnion concentrations as compared to 1933 were: 4.7X for P, 1.6X for CO^2, and 10.1X for nitrate-nitrogen; by 1969 the levels were 1X for P, 1.4X for CO^2, and 8.1X for nitrate-nitrogen. After diversion the winter P concentrations decreased to near those measured in 1950. **REFERENCES**: Edmondson (pers. comm.), Edmondson (1970, 1972 a and b), Millenbach (pers. comm.).

LAKE NAME: Waubesa
LOCATION: Dane Co., Wisconsin, USA
SURFACE AREA: 8.6 km^2
MAXIMUM DEPTH: 10.4 m

PROBLEM: Presence of a large population of undesirable fish species. **RESTORATION OBJECTIVE**: To control the trash-fish population by partial annual removal. **RESTORATION METHODOLOGY**: Carp *(Cyprinus carpio)* were removed by seining each year, 1936-50. The annual harvest ranged from about 108,050 to 676,000 kg. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The catch per unit effort erratically declined from 1938 to 1950; the catch rate in 1950 was about one-third the earlier rate. Total weight removed dropped to one-fifth during the same period due to a reduced effort. Large year-classes appeared at six year intervals. The information suggested that the population was decreasing slowly. **REFERENCES**: Helm (1951).

LAKE NAME: Waubesa
LOCATION: near Madison, Wisconsin, USA
SURFACE AREA: 8.6 km^2
MAXIMUM DEPTH: 10.4 m

PROBLEM: Blue-green algal blooms during the summer. A sewage treatment plant was discharging effluent into the drainage basin. **RESTORATION OBJECTIVE**: To reduce the level of eutrophication by diversion of the sewage effluent. **RESTORATION METHODOLOGY**: The construction of an open channel was completed in 1958. The treated sewage was transported 6.1 km to enter a small creek outside of the drainage basin. The cost was $3,000,000 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Before diversion the treated sewage contributed 75 and 86% of the inorganic nitrogen and soluble phosphorus inflow, respectively. The hydraulic residence time was 3.5 months. In the summer of

1959 there was no reduction in the concentrations of soluble phosphorus, inorganic nitrogen, organic nitrogen, and volatile suspended solids. Three winters after diversion the soluble phosphorus averaged about one-third the pre-diversion level. Before diversion the algal population consisted of over 99% noxious blue-green species. Within one year these species contributed only 25-75% of the population; however, the total quantity of algae remained the same. The increased species diversity was still present in 1972. **REFERENCES**: Fitzgerald (1964, 1965), Lawton (1961), Sonzogni and Lee (1972).

LAKE NAME: Waukomis
LOCATION: Platte Co., Missouri, USA
SURFACE AREA: 14 ha
MAXIMUM DEPTH: 9 m

PROBLEM: Excessive siltation due to urban development in the drainage basin. **RESTORATION OBJECTIVE**: To deepen the infilled areas of the lake in order to enhance boat operation. **RESTORATION METHODOLOGY**: A Sauerman bucket was used for sediment removal on one arm of the lake. The estimated cost of removal is about $1.65 USA/m^3, excluding spoils disposal. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Phillips (pers. comm.).

LAKE NAME: Wellington Reservoir Number 4
LOCATION: Farimer Co., Colorado, USA
SURFACE AREA: 40.5 ha
MAXIMUM DEPTH: 7.6 m

PROBLEM: Overabundant trashfish population. **RESTORATION OBJECTIVE**: To completely eliminate the fish population using a piscicide. **RESTORATION METHODOLOGY**: The lake was treated in October, 1954 using toxaphene in a 60% emulsifiable liquid form at a rate of 0.1 mg/l. Cost of the toxicant was $74 USA. Only a small percentage of the dead fish were removed from the lake. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: A complete kill was indicated by post-treatment surveys. The water clarity of the reservoir increased from about 0.5 to over 4.3 m following treatment. Rotifers reappeared after one month. The lake did not detoxify sufficiently for fish life within seven months. *Daphnia* and the invertebrate bottom fauna returned in large numbers by spring, 1955. **REFERENCES**: Tanner and Hayes (1955).

LAKE NAME: West Pond
LOCATION: near Three Forks, Montana, USA
SURFACE AREA: 5.2 ha
MAXIMUM DEPTH: 5.8 m

PROBLEM: Undesirable characteristics of the fish population. **RESTORATION OBJECTIVE**: To determine some of the limnological effects resulting from piscicide usage. **RESTORATION METHODOLOGY**: The pond was treated with Pro-Noxfish (rotenone) at a concentration of 0.7 mg/l in July, 1957. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: No living fish were found after treatment. The recovered, dead fish yielded 62 kg/ha, about 80% panfish. No change in physical or chemical properties were observed after treatment. There was little effect on the phytoplankton, although *Dinobryon* decreased markedly. Zooplankton were not affected by treatment except that *Bosmina* decreased. Both Tendipedidae and Tubificidae decreased initially. In the littoral zone some species increased, others decreased, and a few were unaffected; however, Tendipedidae were the only organisms eliminated by the treatment. **REFERENCES**: Wollitz (1962).

LAKE NAME: West Lost Lake
LOCATION: Otsego Co., Michigan, USA
SURFACE AREA: 1.5 ha
MAXIMUM DEPTH: 13 m

PROBLEM: Restricted habitat for salmonids during the summer. Relatively unproductive lake. **RESTORATION OBJECTIVE**: To enlarge the salmonid habitat (epilimnion) and to increase the lake's productivity. **RESTORATION METHODOLOGY**: Cold, nutrient-rich hypolimnetic water was pumped to the surface. Water was transferred at the rate of 760 m^3/hr with a shore-mounted centrifugal pump. The intake was placed at the 12 m depth near the lake's center and the surface discharge pipe extended 18 m from shore to a floating barge. The pump ran continuously from 29 July,1952 until 8 August. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The thermocline was lowered from a depth of about 4 m to 7.6 m during pumping; surface water temperatures decreased by about 3° C, but the mean temperature of the lake remained about the same. Before pumping started, oxygen was absent from the bottom 2.5 m; after pumping, oxygen concentrations greater than 5 mg/l were present at all depths and all of the water above the pump intake was suitable for salmonids. Total phosphorus concentrations in the epilimnion temporarily increased but again declined to pre-pumping levels by the end of the experiment. Phytoplankton and periphyton growth was stimulated during a period of normally declining productivity; the mean ash-free dry weight of seston increased from 17.6 mg/l to 23.1 mg/l after seven days. **REFERENCES**: Hooper et al. (1952).

LAKE NAME: Whetzel Pond
LOCATION: Mahomet, Illinois, USA
SURFACE AREA: 3000 m^2
MAXIMUM DEPTH: 2.4 m

PROBLEM: Overabundance of macrophytes, esp. leafy pondweed *(Potamogeton foliosus)* and small pondweed *(P. pusillus)*. **RESTORATION OBJECTIVE**: To remove or control the pondweed. **RESTORATION METHODOLOGY**: Diquat was applied during the first year. Thereafter, granular endothall was used for about three applications per year. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: The macrophytes were reduced greatly during the first year. Afterwards applications were necessary only to remove regrowth in a few scattered areas. Therefore, macrophyte control was obtained quickly but elimination has not been accomplished as yet (6-7 yrs). **REFERENCES**: Hiltibran (pers. comm.; several in-house reports are available), Hiltibran (1963, 1965, 1968).

LAKE NAME: White
LOCATION: Muskegon Co., Michigan, USA
SURFACE AREA: 10.4 km^2
MAXIMUM DEPTH: 24.4 m

PROBLEM: Excessive algal and macrophyte growths; siltation; low levels of dissolved oxygen. Heavy metal pollution, especially chromium. Influx of tannery wastes (hair and hides on the bottom). **RESTORATION OBJECTIVE**: To limit the algal and macrophyte growths and to reduce the siltation. To restore adequate dissolved oxygen levels. To end the influx of miscellaneous pollutants. **RESTORATION METHODOLOGY**: The present wastewater inputs will be diverted from the lake.

Diversion will begin during summer, 1973. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Evaluation and modeling studies are in progress. **REFERENCES**: Arnold (pers. comm.; many reports are available).

LAKE NAME: White Lake
LOCATION: Waupaca Co., Wisconsin, USA
SURFACE AREA: 4.5 km^2
MAXIMUM DEPTH: 3 m

PROBLEM: Periodic winterkills; declining sport fishery. **RESTORATION OBJECTIVE**: To improve the winter dissolved oxygen conditions in order to prevent winterkill. **RESTORATION METHODOLOGY**: A portable tractor-driven irrigation pump with a 30 cm discharge pipe was submerged under the ice. The pumped water was aerated by passing down a 5.8 m chute equipped with baffles and returned to the lake through a hole in the ice. Short-circuiting was prevented by situating the pump on one side of a 5 ha island and the aeration chute on the other side. Aeration began in mid-January, 1973 during an unusually mild winter and the pump ran intermittently until late February. Total cost of the system was about $7,500 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: It was difficult to evaluate the pump's effectiveness; however, dissolved oxygen levels were maintained at substantially higher levels in the vicinity of the island as compared to other locations in the lake. **REFERENCES**: Serns (pers. comm.).

LAKE NAME: White Rock Lake
LOCATION: Dallas, Texas, USA
SURFACE AREA: 2.8 km^2
MAXIMUM DEPTH: 7.3 m

PROBLEM: Accumulation of sediments in the upper reaches of the lake. Low diversity and production of benthos; overabundance of trashfish; and rapid water temperature fluctuations. **RESTORATION OBJECTIVE**: To deepen the upper reaches in order to increase the water storage capacity, improve the ecological balance, and enhance the recreational benefits of this heavily used lake. **RESTORATION METHODOLOGY**: A hydraulic dredging program is planned for about one-third of the lake at an estimated cost of $1,000,000 USA. The project is planned for the fall of 1973; however, numerous objections have been raised by wealthy property owners in the proposed spoils disposal area. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not available at this time. **REFERENCES**: Pearson (pers. comm.), Silvey et al. (1971).

LAKE NAME: Whitewater Lake
LOCATION: Valentine Nat. Wildl. Refuge, Nebraska, USA
SURFACE AREA: 2 km^2
MAXIMUM DEPTH: ---

PROBLEM: Overabundance of carp *(Cyprinus carpio)*. **RESTORATION OBJECTIVE**: To improve the waterfowl habitat and sport fishing through carp removal. To gain experience in the use of piscicides. **RESTORATION METHODOLOGY**: Fintrol (antimycin) was distributed evenly over the lake by helicopter and boat in September, 1967. Sufficient toxicant was added to achieve an average concentration of 7.3 $\mu g/l$ antimycin. The chemical costs were about $22,500 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Treatment produced only a partial kill. Some small carp but few adults were found. After 148 hours, some fish put in livecages in the lake were still alive. A delayed kill was therefore considered unlikely and observations were ended. No adverse effects were observed on the waterfowl and shorebirds, although dead fish were eaten. Fish bioassay experiments indicated that 15 $\mu g/l$ would have been needed for a complete kill. High pH conditions in the lake was the most likely explanation for the failure, but there may have been other factors involved. **REFERENCES**: Berger et al. (1967).

LAKE NAME: Windfall
LOCATION: Forest Co., Wisconsin, USA
SURFACE AREA: 23 ha
MAXIMUM DEPTH: 9.2 m

PROBLEM: Heavy growths of *Chara*, due to eutrophic conditions and past attempts to control other macrophyte species. **RESTORATION OBJECTIVE**: To control the *Chara* growths and establish a diverse macrophyte community. To eliminate macrophytes completely from areas of high recreational use. **RESTORATION METHODOLOGY**: Plot testing involved sand blanketing, harvesting, herbicides, and transplanting. A program was also initiated in 1971 to sensitize the citizens as to the value of macrophytes. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Macrophyte-free areas were maintained by sand blanketing, and a copper herbicide was effective for spot treatments. Harvesting and transplanting were of little value. Within three years after the start of the citizen educational program, a desirable macrophyte, *Potamogeton amplifolius*, replaced *Chara* in large areas of the lake. **REFERENCES**: Nichols (pers. comm.).

LAKE NAME: Wingra
LOCATION: Dane Co., Wisconsin, USA
SURFACE AREA: 1.4 km^2
MAXIMUM DEPTH: 6.4 m

PROBLEM: Presence of an undesirable carp *(Cyprinus carpio)* population. **RESTORATION OBJECTIVE**: To determine the effectiveness of a mechanical removal program (seining). **RESTORATION METHODOLOGY**: Periodic seining and carp removal was conducted on the lake, starting in 1936. The intensity of fishing was dependent primarily on economic considerations. From 1936 to 1953 the seining consisted of one sweep of the entire lake an average of once every three years. From 1953 to 1955 several hauls were made each year with some of the fish again released to permit population estimation. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: During 1953 and 1954 the population was reduced by 90% through natural mortality and the removal program; reproduction was negligible during this period. Continued recruitment into the catchable population occurred from growth of fish already present only. The reproductive failure could not be attributed to a specific cause, but resulted in carp population control by 1955. **REFERENCES**: Neess et al. (1957).

LAKE NAME: Winnebago
LOCATION: Winnebago Co., Wisconsin, USA
SURFACE AREA: 557.7 km^2
MAXIMUM DEPTH: 6.4 m

PROBLEM: Deteriorating sport fishery; overabundant drum *(Aplodinotus grunniens)*. **RESTORATION OBJECTIVE**: To evaluate the effects of drum removal on the remaining population and on the other fish species. **RESTORATION METHODOLOGY**: An intensive removal program was conducted for 12 years using hoop nets, trap nets, and trawls. The investigation and removal program began in 1955. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: An initially heavy removal program, 5.4 x 10^6 kg of drum during 1955-57, resulted in a decided increase in the condition of the drum; however, this change in condition was lost after 1962 because of a decrease in fishing intensity. The sport fishery appeared to benefit from the removal program; however, a positive correlation could not be demonstrated. In the beginning, the drum population was composed mostly of older, larger fish, but after 1962 smaller, younger fish predominated. The growth rate was unaffected by the harvest. The number of gamefish caught and released definitely increased after 1959 for white bass *(Roccus chrysops)* and black crappie *(Pomoxis nigromaculatus)* and also apparently for walleye *(Stizostedion vitreum)*, sauger *(Stizostedion canadense)* and yellow perch *(Perca flavescens)*. **REFERENCES**: Priegel (pers. comm.), Priegel (1971).

LAKE NAME: Winnisquam
LOCATION: Belknap Co., New Hampshire, USA
SURFACE AREA: 17.3 km^2

MAXIMUM DEPTH: 47 m

PROBLEM: Nuisance blue-green algal blooms; fishkills due to oxygen depletion. Eutrophic conditions apparently induced by the influx of municipal effluents. **RESTORATION OBJECTIVE**: To limit the algal growths and improve the dissolved oxygen conditions by treatment with copper sulfate, artificial destratification, and reduction of the nutrient loading. To enhance the aesthetics and recreational value of the lake. **RESTORATION METHODOLOGY**: Diversion of the effluents away from the lake will probably be implemented in the near future and a tertiary sewage treatment plant has been proposed. During 1961-72 copper sulfate was usually added at the rate of 5-7 kg/ha once each summer; all applications were accomplished by "bag dragging" in order to obtain an even distribution to the 3.1 m depth. Chemical costs were about $51 USA/kg in 1972. Destratification was initiated in August, 1970 and was continued through October of that same year. Mixing in subsequent years (1971 and 1972) was from May through October. System operation (including power and maintenance) in 1970 cost $6,000 and in 1971, $9,813. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Seasonal nuisance blooms of blue-green algae were controlled by copper sulfate treatment; a fishkill in August, 1967 following algicide application was probably due to the release of toxin from the dead *Aphanizomenon*. Water clarity was improved during destratification. **REFERENCES**: Byers and Rutherford (pers. comm.), Frost (pers. comm.), Greundling and Mathieson (1969), Manfredonia (pers. comm.; a report is in preparation), Sawyer (1970), Sawyer et al. (1968).

LAKE NAME: Lake Winona
LOCATION: Winona, Minnesota, USA
SURFACE AREA: 1.3 km^2

MAXIMUM DEPTH: 11 m

PROBLEM: Winter oxygen depletion; fishkills. Overabundance of buffalo *(Ictiobus cyprinellus)*. Turbid water; lack of macrophytes; no sport fishery. Influx of urban runoff. **RESTORATION OBJECTIVE**: To restore and maintain a desirable fish population. To provide recreational angling, especially for young children and the elderly. To increase the quality of the water for swimming. **RESTORATION METHODOLOGY**: In summer, 1973 an electric weir will be constructed at the lake outlet in order to prevent the immigration of trashfish. The design and construction costs will be $7,000 USA. Three "Helixor" aeration systems will also be installed at a cost of $12,000. The entire drainage basin and lake will be treated with rotenone in fall, 1973 and restocked with northern pike *(Esox lucius)* and bluegill *(Lepomis macrochirus)*. Future research will be directed toward curtailment of the nutrient loading, primarily the storm sewers. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: Results are not yet available. **REFERENCES**: Fremling (pers. comm.).

LAKE NAME: Winter Park lakes (14)
LOCATION: Winter Park, Florida, USA
SURFACE AREA: ---

MAXIMUM DEPTH: ---

PROBLEM: Lakes unusable due to macrophyte growths. **RESTORATION OBJECTIVE**: To control the macrophytes in order to enhance the recreational potential of the lakes. **RESTORATION METHODOLOGY**: The macrophytes were harvested mechanically at a cost of about $87.80 USA/ha. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 4580 m^2 were harvested/day; six of the lakes were treated in 10 months. Although the harvesting units were relatively inefficient, the project was considered of value because the lakes were made more usable for recreation. **REFERENCES**: Blanchard (1966).

LAKE NAME: Youngerman Pond
LOCATION: southern USA
SURFACE AREA: 3.3 ha

MAXIMUM DEPTH: 1.8 m

PROBLEM: Overcrowded, slow-growing panfish; unbalanced fish population. **RESTORATION OBJECTIVE**: To test the effectiveness of a new piscicide–antimycin–for selectively thinning the overabundant species. **RESTORATION METHODOLOGY**: The liquid formulation of antimycin, Fintrol-Concentrate, was used in the shallow areas of the pond. About 50% of the pond was treated on 14 May, 1968 at concentrations of 1.2 to 1.6 μg/l. The toxicant was spilled on the surface in front of a moving boat. The chemical cost was $21.20 USA. **RESULTS (OR STATUS FOR ONGOING PROJECTS)**: About 71 kg of panfish/ha were killed. No largemouth bass *(Micropterus salmoides)* died but over 10 kg of five other species were killed on a per hectare basis. **REFERENCES**: Burress (1970).

PART THREE: METHODOLOGY

Pertinent information was acquired through a systematic search of the literature and personal communication with the people engaged in lake restoration-related activities.

The scope of literature reviewed included foreign as well as domestic documents. In addition to journals, an extensive effort was made to acquire agency and special project reports, and other informal materials. This endeavor was conducted through a cooperative arrangement with the information scientists at the Information Services Division of Engineering and Physical Sciences Library, University of Wisconsin. Utilization of their literature search and procurement talents permitted a significant increase in the amount of scientific materials that could be reviewed within the one year project period.

Various referencing services were utilized during the literature search; the primary ones are shown in Table 15. The usual procedure was: (1) examination of the subject index in order to identify potentially pertinent materials (condensed list of key words; Table 16), (2) review of the abstracts prior to final selection of the documents to be procured, and (3) inspection of the bibliographies of procured documents. This basic search and procurement format was adjusted as necessary for the many additional information sources utilized.

A mail survey was also conducted to provide access to the information base independent of the literature search. This was done primarily to acquire up-to-date information concerning current or recently completed activities. The initial mailing list was compiled mostly, but not exclusively, from the sources in Table 17. The various agencies and individuals were contacted by letter and accompanying questionnaire (Append. A) dated 15 November, 1972. In addition, several organizations (Table 18) were asked to include a request for information (Append. B) in one of their publications. As a result of additions recommended by questionnaire recipients and people responding to the news releases, the final mailing list contained approximately 8000 entries—5000 domestic and 3000 foreign. Information furnished via returned questionnaire was supplemented or clarified through ensuing communique whenever necessary and possible.

TABLE 15. Primary Services/Sources Utilized During Literature Search

Biological Abstracts	1970, 1971
Chemical Abstracts	1971, 1972
Dissertation Abstracts International	Jan.-June, 1970
Engineering Index	1970, 1971
Eutrophication Abstracts	1972 to present
Hydata	1972 to present
OWRR/WRSIC Data Base	searched Aug., 1972
Pollution Abstracts	1970, 1971
Reference Service, Denver Public Library	searched Feb., 1973
Sport Fishery Abstracts	1966 to present
U.S. Government Research and Development Reports	1970, 1971
U.S. Monthly Catalog of U.S. Government Publications	1970, 1971
Water Pollution Abstracts	1970

TABLE 16. Condensed List of Key Words Utilized During Literature Search

Aerat...
Aerobic...
Alga...
Algicides
Bacteria...
Bibliography
Biocides
Dredg...
Ecology
Economics
Equipment
Eutrification
Eutroph...
Farm...
Fertil...
Fish...
Habitat Improvement
Harvest...
Herbicides
Impoundments
Industrial Wastes...
Insecticides
Lagoon...
Lake...
Limnology
Management
Nitr...
Nutrients
Pesticides
Phosph...
Phytoplankton
Photosynthesis
Plankton
Pollut...
Pond...
Product...
Research
Reservoir...
Sediment...
Sewage
Silt
Vegetation
Waste...
Water...
Weed...

TABLE 17. Primary Sources Utilized in Compiling the Lake Restoration Questionnaire Mailing List

American Society of Limnology and Oceanography (membership list, 1970).

Eutrophication Program of the University of Wisconsin Water Resources Center (August, 1972 mailing list for Eutrophication: A Bimonthly Summary of Current Literature and a compiled list of state and federal agencies participating in water-related activities).

Hiatt, R. W. (ed.) 1963. World Directory of Hydrobiological and Fisheries Institutions. Garamond Press; Baltimore Maryland. 320 p.

International Association of Theoretical and Applied Limnology (membership list, 1968).

Ketelle, M. J. and P. D. Uttormark. 1971. Problem Lakes in the United States. Water Resources Center, University of Wisconsin. Technical Report 16010 EHR 12/71. Madison, Wisconsin. 282 p. (list of information sources).

Larsen, C. M. (ed.) 1971. A World List of Fishery Limnologists. Food and Agriculture Organization of the United Nations, FAO Fisheries Technical Report No. 108. Rome, Italy. 43 p.

Office of Water Resources Research. 1972. Water Resources Research Catalog, Volume 7. Water Resources Scientific Information Center. Washington, D. C. (subject index and project descriptions examined for pertinent activities).

Special Committee for the International Biological Programme, International Council of Scientific Unions. 1972. Directory of National Participation in IBP. Cable Printing Services, London, England (selected personnel potentially knowledgeable of pertinent studies).

The National Wildlife Federation. 1971. Conservation Directory 1971. Washington, D. C. 152 p. (selected organizations/officials concerned with natural resource management).

United States Dept. of State. 1972. Foreign Service List. Dept. of State Pub. 7802. U. S. Govt. Printing Office; Washington, D. C. 88 p. (list of embassies or consulates).

Weed Science Society of America (selections from membership list, 1971).

TABLE 18. Organizations Asked to Publicize the Project and Request Assistance From Their Membership

I. Cooperation confirmed; gratis basis.
  - American Association for the Advancement of Science (Science Education News; and Science).
  - American Chemical Society (Chemical and Engineering News).
  - American Fisheries Society (AFS Newsletter).
  - American Geological Institute (Geotimes).
  - American Society of Agronomy (Agronomy News).
  - American Society of Civil Engineers (Environmental Engineering Division Newsletter).
  - American Society of Sanitary Engineering (A.S.S.E. News-letter).
  - American Water Resources Association (Water Resources Bulletin).
  - International Association for Ecology (INTERCOL).
  - National Water Resources Association (Water Life).
  - Soil Conservation Society of America (Journal of Soil and Water Conservation).
  - Sport Fishing Institute (SFI Bulletin).
  - The Institute of Ecology (TIE Report).
  - Trends Publishing, Inc. (Environment Report).

II. Cooperation unconfirmed; gratis basis.
  - American Institute of Biological Sciences.
  - American Society of Agricultural Engineers.
  - Ecological Society of America.
  - Hyacinth Control Society.
  - Institute of Environmental Sciences.
  - International Association for Pollution Control.
  - Society of American Foresters.
  - United States Army, Corps of Engineers.
  - Water Pollution Control Federation.
  - Weed Science Society of America.

III. Cooperation confirmed; payment basis.
  - Plenum Publishing Corp. (American Scientist).

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ABOABA, F.O., H.D. BRUHN, R.G. KOEGEL, and D.F. LIVERMORE
1971. Some fundamental principles of dewatering aquatic vegetation. Am. Soc. Agr. Eng., Pap. No. 71-599.

ADAMS, C.E., JR.
1973. Removing nitrogen from waste water. Environ. Sci. and Technol. 7(8):696-701.

ADOLPH, K.W. and R. HASELKORN
1972. Photosynthesis and the development of blue-green algal virus N-1. Virology 47:370-374.

AGRICULTURAL RESEARCH
1968. Biological control of aquatic weeds. February:8-9.

AHLGREN, I.
1972. Changes in Lake Norrviken after sewage diversion. Verh. Int. Ver. Limnol. 18:355-361.
1973. Limnologiska Studier av Sjön Norrviken. III. Avlastningens effekter [In Swedish]. Uppsala Universitet, Limnologiska Institutionen. Uppsala, Sweden. 80 p.

AHLING, B.
1970. The recovery process of a lake which received waste water from an ore dressing plant, p. 61-70. *In:* International symposium on water pollution control in cold climates. Environ. Prot. Agency, Water Pollut. Control Res. Ser. 16100 EXH 11/71. Washington, D.C.
1972. Gråskarpsförsöket i Ösbysjön 1972 [In Swedish]. Institutet för Vatten-och Luftvårds–forskning, B-publ. 143. Stockholm, Sweden. 27 p.

AHLING, B. and A. JERNELÖV
1971a. Weed control with grass carp in Lake Ösbysjön. Swed. Water and Air Pollut. Res. Lab., Stockholm, Sweden. 15 p.
1971b. Makrofytkontroll med gråskart i Ösbysjön. Vatten, No. 3.

AHLING, B. and P. RÅGHALL
1973. Fosforreduktion med aluminiumsulfat i Grängesbergsviken and Södra Hörken [In Swedish]. Institutet för Vatten-och Luftvårdsforskning, B-publ. 153. Stockholm, Sweden. 22 p.

AHMAD, N.
1968. Review of research work done by directorate of fisheries, West Pakistan. Agric. Pak. 19:557-572.

AHRENS, J.F. and P.M. BLOCK
1972. Phytotoxicity and persistence of simazine in a shallow lake. Proc. Northeast. Weed Sci. Soc. 26:166.

ALHONEN, P.
1972. Gallträsket: the geological development and paleolimnology of a small polluted lake in Southern Finland. Commentationes Biologicae, no. 57. Societas Scientiarum Fennica. 34 p.

ALIYEV, D.S. and R.Y. BESSMERTNAYA
1968. The use of grass carp to control the larvae of bloodsucking mosquitoes. Probl. of Ichthyol., Am. Fish. Soc. 8(2):319-321.

ALLAN, J.R. and W. YARISH
1972. Herbicide trials on submergent aquatic plants, Lake Wabanum, Alberta. Res. Rep., Can. Weed Comm., West. Sect. 366 p.

ALLISON, D.
Undated. Copper sulfate used in bluegill population control. Ohio Dep. Nat. Resour., Div. of Wildl. Publ. 10. 4 p.

ALLSOPP, W.H.L.
1960. The manatee: ecology and use for weed control. Nature 188:762.

AMARAL e SILVA, C.C.
1972. Poluicão das Águas e Eutrofizacão [In Portugese, English summary]. Faculdade de Saúde Pública, Universidade de São Paulo. Brazil. 69 p.

AMBÜHL, H.
1960. Die Nährstoffzufuhr zum Hallwilersee. Schweiz. Z. Hydrol. 22:563.
1962. Die kunstliche Beluftung des Pfaffikersees, Verband Schweizerischer Abwasserfachleute–A.S.P.E.E. [In German]. Verbands-Berich 77/3 (Dec.).
1967. Impoundment destratification by mechanical pumping-discussion. Am. Soc. Civ. Eng.,, Sani. Eng. Div. 83 (SA4):141-143.

AMERICAN CHEMICAL SOCIETY
1973a. Currents. Environ. Sci. and Technol. 7(8):671.
1973b. How fast are U.S. lakes aging and why? Environ. Sci. and Technol. 7:198-199.

AMERICAN CITY MAGAZINE
1971. Out with the algae safely. 86(6):84-86.

ANDERSON, G.C.
1961. Recent changes in the trophic nature of Lake Washington. A review, pp. 27-33. *In:* Algae and metropolitan wastes. Robt. A. Taft Sanit. Eng. Cent., Tech. Rep. W61-3. Cincinnati, Ohio.

ANDERSON, R.H.
1973. Yugoslav town reviving a lake that pollution killed. The N.Y. Times, July 23.

ANDERSON, W.
1971. Hydrologic considerations in draining Lake Apopka–a preliminary analysis, 1970. U.S. Geol. Surv., Open-file Rep. 71004. Tallahassee, Fla. 40 p.

ANDERSSON, G., G. CRONBERG, and C. GELIN
1973. Planktonic changes following the restoration of Lake Trummen, Sweden. Ambio 2(1-2):44-47.

ANTHONY, S.
1969. Algae handled efficiently by Augusta water district. Water and Sewage Works 116:185-189.

ARMSTRONG, D.E. and K.W. LEE
1972. Mobility of phosphorus in dewatered sediments. Rep. to the Inland Lake Demonstr. Proj., Upper Great Lakes Reg. Comm., Madison, Wis.

AVAULT, J.W., JR.
[?] Preliminary studies with grass carp for aquatic weed control. Agric. Exper. Sta., Auburn. Univ. Ala.

AVAULT, J.W., JR., R.O. SMITHERMAN, and E.W. SHELL
1966. Evaluation of eight species of fish for aquatic weed control. Proc. FAO Symp. on Warmwater Pond Fish Culture pp. 110-122. Rome, Italy.

BABCOCK, W.H.
1972. Aeration studies. Colo. Fish. Res. Rev. No. 7, pp. 17-18.

BAGNALL, L.O., T.W. CASSELMAN, J.W. KESTERSON, and H.F. HELLWIG
1971. Aquatic forage processing in Florida. Agric. Eng., Pap. No. 71-536.

BAILEY, J.A.
1965. Commercial possibilities of dehydrated aquatic plants. Proc. Weed Conf. 18:543-551.

BAILEY, W.M.
1972. Arkansas evaluation of the desirability of introducing the white amur (*Ctenopharyndogon idella,* Val.) for control of aquatic weeds. Arkansas Game and Fish Comm. Little Rock, Arkansas.

BAILEY, W.M. and R.L. BOYD
[?] A preliminary report on spawning and rearing of grass carp in Arkansas. Arkansas Game and Fish Comm. Little Rock, Arkansas.
1970. Some observations on the white amur in Arkansas. Presented at the 24th Annu. Conf. of Southeast. Assoc. of Fish and Game Comm. Atlanta, Ga.

BALABANOVA, Z.M.
1970. Industrial wastes as factors of the chemical improvement of dying lakes [In Russian]. Okhr. Prir. Urale 1970, 7, 167-171.

BALDWIN, J. and R.A. SWEENEY
1973. Annotated bibliography of Lake Ontario limnological and related studies, Vol. III–Physical. Environ. Prot. Agency, Ecol. Res. Ser., EPA-R3-73-028c. Washington, D.C. 207 p.

BALOCH, G.M., A.G. KHAN, and M.A. GHANI
1972. Phenology, biology and host-specificity of some stenophagus insects attacking *Myriophyllum* spp. in Pakistan. Hyacinth Control J. 10:12-16.

BALVAY, G.
1968. Apercu sur l'etat des trois grands lacs savoyards. Revue de l'Institut Pasteur de Lyon 1(3):431-441.

BALVAY, G. and P. LAURENT
1972. Etude de la pollution du lac du Bourget. Station d'Hydrobiologie Lacustre, Thonon-les-Bains, France. 19 p. (mimeo).

BANDOW, F.
1972. Algae control through removal of available nutrients. Job Prog. Rep. F-26-R-3, Minn. Dep. of Nat. Resour., Area Fish. Hdqtrs., Waterville, Minn. 19 p.

BARKER, J.L.
1972. An evaluation of the use of herbicides to control aquatic weeds in six Pennsylvania recreational lakes. U.S. Geol. Surv. Prof. Pap. 800–C, pp. C221-C232.

BARNETT, R.H.
1971. Reservoir destratification improves water quality. Public Works 102:60-65, 120.

BARROWS, M.B.
1939. Elimination of yellow perch from a lake by use of derris root. J. Wildl. Mgt. 3:131-133.

BARTSCH, A.F.
1954. Practical methods for control of algae and water weeds. U.S. Public Health Serv. Public Health Rep. 69:749-757.
1968. Statement of eutrophic conditions in Lake Michigan. Proc. Conf. on Pollution of Lake Michigan and Its Tributary Basin, pp. 649-750, Chicago, Illinois. (No. 0-312-667, U.S. Gov. Print. Off., Washington, D.C.).

BEARD, H.R.
1926. Nutritive value of fish and shellfish. Rep. U.S. Comm. of Fish. for 1925, pp. 501-552.

BEARD, T.D.
1967. Evaluation of a minimum size limit on largemouth bass. M.A. Thesis, Indiana Univ. 26 p.
1969. Impact of an overwinter drawdown on the aquatic vegetation in Murphy Flowage, Wisconsin. Wis. Dep. Nat. Resour., Res. Rep. No. 43. Madison, Wis. 16 p.
1971. Impact of an overwinter drawdown on feeding activities of northern pike. Unpubl. rep. no. 4. Bur. of Res., Wis. Dep. of Nat. Resour. Madison, Wis. 6 p.
1973. Overwinter drawdown. Impact on the aquatic vegetation in Murphy Flowage, Wisconsin. Wis. Dep. of Nat. Resour., Tech. Bull. No. 61. Madison, Wis. 13 p.

BECKMAN, W.C.
1940. Increased growth rate of rock bass, *Ambloplites rupestris* (Rafinesque), following reduction in density of the population. Trans. Amer. Fish. Soc. 70:143-148.
1946. Further studies on the increased growth rate of the rock bass *Ambloplites rupestris* (Rafinesque), following the reduction in density of the population. Trans. Amer. Fish. Soc. 72:72-78.

BENGTSSON, L., H. BERGGREN, O. MEYER, and B. VERNER
1972. Restaurering av sjöar med kulturbetingat hypolimniskt syrgasdeficit. Limnologiska Institutionen, Lunds Universitet Centrala Fysiklaboratoriet, Atlas Copco AB.

BENNDORF, J.
In press. Prognose des Stoffhaushalters von Staugewassern mit Hilfe kontinuier-licher and semikontinuierlicher biologisher Modelle II: Prufung der Prognosegenauigkeit. Int. Revue jes. Hydrobiol. 57.

BENNETT, G.W.
1945. Overfishing in a small artificial lake. Bull. Ill. Nat. Hist. Surv. 23(3):373-406.
1949. The bass-bluegill combination in a small artificial lake. Bull. Ill. Nat. Hist. Surv. 24(3):377-412.
1950. Experimental largemouth bass management in Illinois. Trans. Amer. Fish. Soc., 80:231-239.
1954. Largemouth bass in Ridge Lake, Coles County, Illinois. Bull. Ill. Nat. Hist. Surv. 26(2):217-276.
1962. Management of artificial lakes and ponds. Reinhold Publ. Corp., New York, N.Y. 283 p.

BENNETT, G.W., H.W. ADKINS, and W.F. CHILDERS
1969. Largemouth bass and other fishes in Ridge Lake, Illinois, 1941-1963. Bull. Ill. Nat. Hist. Surv. 30(1):1-67.

BERGER, B.L.
1965. An application of Fintrol-5 (antimycin) to Veterans Memorial Park Pond, West Salem, Wisconsin. U.S. Dep. of the Inter., Fish Control Lab. La Crosse, Wis. 11 p.

BERGER, B.L., P.A. GILDERHUS, and R.E. LENNON.
1967. Attempted reclamation of Whitewater Lake, Valentine National Wildlife Refuge, Nebraska. U.S. Dept. of the Interior, Fish Control Laboratory. La Crosse, Wisconsin. 12 p.

BERGER, ir. C.
1970. Over de hoedanighuid van het water in de meren rondom flevoland van 1966 tot 1970 [In Dutch]. Flevobericht Nr. 75. Ryksdienst voor de Ijsselmeerpolders, Zwolle. 45 p.

BERNARD, J.G. and G. ROCHON
1971. Etude écologique du lac Rose cté Nicolet. CENTREAU, Pavillon Pouliot, Université Laval. Québec, Canada.

BERNHARDT, H.
1963. Erste Ergebnisse über die Beluftungsversuche an der Wahnbachtalsperre [In German]. Vom Wasser 30:11-49.
1967. Aeration of Wahnbach Reservoir without changing the temperature profile. Amer. Water Works Assoc. 63:943-963.
1968. Belufting stehender Wasser, aufgezeigt am Beispeil der Wahnbachtalsperre [In German]. Gewasserschutz-Wasser-Abwasser, 128-160.

BERNHARDT, H. and G. HOTTER
1967. Moglichkeiten der Verhinderung anaerober Verhaltnisse in einer Trinkwassertalsperre wahrend der Sommerstagnation [In German]. Arch. Hydrobiol. 63(6):404-428.

BERNHARDT, H., J. CLASEN, and H. SCHELL
1971. Phosphate and turbidity control by flocculation and filtration. Amer. Water Works Assoc. 63(6):355-368.

BEUSCHOLD, E.
1966. Entwicklungslendenzen der Wasserbeschaffenheit in den Ostharz–Talsperren. Wiss. Z. d. Karl Marx Univ. Leipzig Math. Nat. Reihe H. 4, 853-869.

BEYERLE, G.B.
1970. A study of two northern pike-bluegill populations. Mich. Dep. of Nat. Resour., Res. and Dev. Rep. No. 194. 13 p.

BEYERLE, G.B. and J.E. WILLIAMS
1967. Attempted control of bluegill reproduction in lakes by the application of copper sulfate crystals to spawning nests. Prog. Fish-Cult. 29(3):150-155.

BEZIRKSAMT REINICKENDORF VON BERLIN
1971. Dokumentation über die Arbeit der Kommission zur Untersuchung und Erhaltung des Erholungsgebietes Tegeler See.

BHAGAT, S.K. and J.T. ORSBORN
1971. Water quantity and quality studies of Vancouver Lake, Washington. Wash. State Univ., Pullman, Wash. 35 p.

BHAGAT, S.K., W.H. FUNK, and D.L. JOHNSTONE
1972. Correlated studies of Vancouver Lake water quality prediction study. Environ. Prot. Agency, Environ. Prot. Tech. Ser., EPA-R2-72-111. Washington, D.C. 120 p.

BIEDERMAN, W.J. and E.E. FULTON
1971. Destratification using air. Amer. Water Works Assoc. 63(7):462-466.

BILL, S.M.
1969. The water weed problem in Australia. Hyacinth Control J. 8(1):1-6.

BIRGE, E.A. and C. JUDAY
1922. The inland lakes of Wisconsin. The plankton. I. Its quantity and chemical composition. Wis. Geol. and Nat. Hist. Surv., Bull. No. 64, Sci. Ser. No. 13, pp. 1-222.

BJÖRK, S.
1971. Restoration of the lakes. Lund Universitets, Limnologiska Institution. Lund, Sweden. 23 p.
1972a. Bringing sick lakes back to health. Teknisk Tidskrift, Swed. Assoc. Eng. Arch. 102(11):112-120.
1972b. Swedish lake restoration program gets results. Ambio 1(5):153-165.
1972c. Statens naturvårdsverks utredning beträffande Hornborgasjöns framtid. Den limnologiska delutredningen. Förutsättningar, metoder och kostnader för Hornborgasjöns restaurering. Limnol. Inst. Lund (mimeo).

BJÖRK, S. et al.
1972. Ecosystem studies in connection with the restoration of lakes. Verh. Int. Limnol. 18:379-387.

BLACK, J.D.
1946. Natures own weed killer–the German carp. Wis. Conserv. Bull., 11:3-7.

BLACKBURN, R.D. and L.W. WELDON
1965. A fresh-water snail as a weed control agent. Proc. South. Weed Conf. 18:589.

BLANCHARD, J.L.
1966. Aquatic weed harvester operational report. Proc. South. Weed Conf. 18:477-479.

BLOMQUIST, K., M. CRONHOLM, and A. JERNELÖV
1971. Försök med fosfatreduktion genom kemisk fällning i Långsjön [In Swedish, English summary]. Vatten 27(2).

BORN, S.M., T.L. WIRTH, J. O. PETERSON, J.P. WALL, and D.A. STEPHENSON
1973a. Dilutional pumping at Snake Lake, Wisconsin–a potential renewal technique for small eutrophic lakes. Wis. Dep. Nat. Resour. Tech. Bull. No. 66. Madison, Wis. 32 p.

BORN, S.M., T.L. WIRTH, E.M. BRICK, and J.O. PETERSON
1973b. Restoring the recreational potential of small impoundments: the Marion Millpond experience. Inland Lake Demonstr. Proj., Upper Great Lakes Reg. Comm., Madison, Wis. 48 p.

BOROVICKA, R.L.
1961. The use of toxaphene for fish eradication in lakes and reservoirs of Oregon. Proc. Ann. Conf. West. Assoc. State Game and Fish Comm. 41:229-233.

BOULIER, G.A.
1971. Artificial circulation enhances multiple usage of reclaimed waste water at South Lake Tahoe. Presented at the Int. Symp. on Man-Made Lakes. Knoxville, Tenn.

BOWERS, C.C.
1955. Selective poisoning of gizzard shad with rotenone. Prog. Fish-Cult. 17:134-135.

BOWLES, L.G.
Undated. Vertical distribution of zooplankton. Job Completion Rep., Okla. Proj. F-27-1, Job 3.

BOYCE, D.R. and C.E. BEER
1973. Mandatory erosion control and response to Iowa's Conservancy District Law. J. Soil and Water Conserv. 28(4):180-181.

BOYTER, C.J. and M.P. WANIELISTA
1973. Review of lake restoration procedures. Water Resour. Bull. 9(3):499-511.

BRASHIER, C.K., C.L. CHURCHILL, and G. LEIDAHL
1973. Effect of silt and silt removal in a prairie lake. Environ. Prot. Agency, Ecol. Res. Ser., EPA-R3-73-037. Washington, D.C. 200 p.

BREZONIK, P.L. and G.F. LEE
1968. Denitrification as a nitrogen sink in Lake Mendota, Wisconsin. Environ. Sci. and Technol. 2:120-125.

BREZONIK, P.L., J.J. DELFINO, and G.F. LEE
1969. Chemistry of N and Mn in Cox Hollow Lake, Wisconsin, following destratification. Amer. Soc. Civ. Eng., Sani. Eng. Div. 95 (SA5):929-940.

BRICE, R.M. and C.F. POWERS
1969. The Shagawa Lake, Minnesota, eutrophication research project. Proc. Eutrophication Biostimulation Assessment Workshop. Fed. Water Pollut. Control Adm. Corvallis, Oreg.

BRINKHURST, R.O.
1972. The role of sludge worms in eutrophication. Environ. Prot. Agency, Rep. R3-72-004 (16010ECQ). 68 p.

BRONSE, D.D.
1966. Copper sulfate air spray cures lake algae problem. Water and Pollut. Control 104(4):25-27.

BROOK, A.J. and W.B. WOODWARD
1956. Some observations on the effects of water inflow and outflow on the plankton of small lakes. J. Anim. Ecol. 25:22-35.

BROOKER, M.P. and R.W. EDWARDS
1973. Effects of the herbicide paraquat on the ecology of a reservoir. Freshwater Biol. 3(2):157-175.

BROWMAN, M.G. and R.F. HARRIS
1973. Interaction of soluble phosphate with aluminum hydroxide in lakes. Rep. to the Inland Lake Demonstr. Proj., Upper Great Lakes Reg. Comm. Madison, Wis.

BROWN, D.J., T.G. BRYDGES, W. ELLERINGTON, J.J. EVANS, M.F.P. MICHALSKI, G.G. HITCHIN, M.D. PALMER, and D.M. VEAL
1971. Progress report on the destratification of Buchanan Lake. Ont. Water Res. Comm., AID for Lakes Program (Artificially Induced Destratification).

BRUHN, H.D. and D.F. LIVERMORE
1970. Physical properties and processing characteristics of macrophytes as related to mechanical harvesting. Ann. Conf. Amer. Soc. Agric. Eng., Pap. No. 70-582. St. Joseph, Mich. 17 p.

BRUHN, H.D., D.F. LIVERMORE, and F.O. ABOABA
1971. Processing characteristics of macrophytes as related to mechanical harvesting. Hydrobiologia 12.

BRYAN, J.G.
1964. Physical control of water quality. J. Br. Water Works Assoc., Proc. Glasgow Conf. Glasgow, United Kingdom.

BUCK, D.H., M.A. WHITACRE, and C.F. THORIS, III
1960. Some experiments in the baiting of carp. J. Wildl. Manage. 24(4):357-364.

BUCKLEY, J.A.
1971. Effects of low nutrient dilution water and mixing on the growth of nuisance algae. M.S. Thesis, Univ. of Wash. Seattle, Wash. 116 p.

BUGLEWICZ, E.G.
1972. The impact of reduced light penetration on a eutrophic farm pond. M.S. Thesis, Univ. of Nebr.

BULLARD, W.E.
1966. Effects of land use on water resources. Water Pollut. Control Fed. 38:645-659.

BUNTING, D.L.
1968. The productivity of a lake polluted by organic wastes derived primarily from septic tanks. Termination Rep., U.S. Dep. of the Inter., Off. of Water Resour. Res., Proj. A-008-TENN. 14 p.

BURGESS, J.E.
1966. Some effects of cultural practices on aquatic environmental and native fish populations. Proc. Ann. Conf. Southeast. Assoc. Game Comm. 19:225-235.

BURNS, C.W. and S.F. MITCHELL
In press. Seasonal succession and vertical distribution of phytoplankton in Lake Hayes and Lake Johnson, South Island, New Zealand. N.Z. J. of Marine and Freshwater Res.

BURNS, J.M., JR.
1966. Reservoir "turn over" improves water quality. Water and Wastes Eng. 3:81.

BURNS, N.M. and C. ROSS
1972. Project hypo. An intensive study of the Lake Erie central basin hypolimnion and related surface water phenomena. Canada Centre for Inland Waters, Pap. No. 6 and Environ. Prot. Agency, Tech. Rep. TS-05-71-208-24. 182 p.

BURRESS, R.M.
1968. Antimycin for controlling sunfish populations in ponds. Farm Pond Harvest, 2:11-12, 22.
1970. Improved method of treating ponds with antimycin A to reduce sunfish populations. Proc. Ann. Southeast. Assoc. Game and Fish Comm. 24:464-473.

BURRESS, R.M. and C.W. LUHNING
1969a. Field trials of antimycin as a selective toxicant in channel catfish ponds. U.S. Dep. Inter., Bur. of Sport Fish. and Wildl., Invest. in Fish Control No. 25. Washington, D.C. 12 p.
1969b. Use of antimycin for selective thinning of sunfish populations in ponds. U.S. Dep. Inter., Bur. of Sport Fish. and Wildl., Invest. in Fish Control No. 28. Washington, D.C. 10 p.

BUSBEE, R.L.
1969. The limnological effects of bottom-water discharge on impounded waters. Ph.D. Thesis, Univ. of Georgia. Athens, Ga. 123 p.

BUSBY, M.W.
1973. Air-injection at Lake Cachuma, California. U.S. Geol. Surv., Open-file Rep. Menlo Park, Calif.

BUSH, R.M. and E.B. WELCH
1971. Plankton associations and related factors in a hypereutrophic lake. Partial Proj. Completion Rep., Dep. of Civ. Eng., Univ. of Wash. Seattle, Wash. 30 p.

BUSSELMAN, F. and D. CALLIES
1971. The quiet revolution in land use control. U.S. Counc. Environ. Qual. Washington, D.C. 327 p.

CAHOON, W.G.
1953. Commercial carp removal at Lake Mattamuskeet, N.C. J. Wildl. Manage. 17(3):312-317.

CALHOUN, A.
1966. Habitat protection and improvement, pp. 40-48. *In:* Inland fisheries management. Calif. Dep. Fish and Game. Sacramento, Calif.

CANADA CENTRE FOR INLAND WATERS
[?] Evaluation of procedures for removing and decontaminating bottom sediments in the lower Great Lakes. Unpubl. rep. Dep. of Environ., Can. Cent. for Inland Waters. Burlington, Ont.

CARRANZA, C. and J. WALSH
1972. A study of nutrient sources as pertaining to the duckweed problem in Rubberthread Pond in Easthampton, Massachusetts. Consult. Rep., Bay State Environ. Consultants. Springfield, Mass. 66 p.

CARTER, E.R.
1956. Investigations and management of the Dewey Lake fishery. Ky. Dep. of Fish and Wildl., Fish. Bull. No. 19. Frankfort, Ky. 20 p.

CARTER, J.P.
1963. Experimental crappie removal. Ky. Dep. of Fish and Wildl. Resour. Final Rep., Proj. F-21-R. Frankfort, Ky. 18 p.

CANTER, H.M. and J.W.G. LUND
1948. Studies on plankton parasites. I. Fluctuations in numbers of *Asterionella formosa* Hass. in relation to fungal epidemics. New Phytol. 47:238-261.

CARLSON, J.R.
1971. Prognosis for control of water hyacinth by arthropods. Hyacinth Control J. 9(1):31-34.

CHAPMAN, W.H., H.L. FISHER, and M.W. PRATT
1968. Concentration factors of chemical elements in edible aquatic organisms. Lawrence Radiat. Lab., Univ. Calif. Livermore, Calif. 50 p.

CHEW, L.E. and J.G. STANLEY
1973. The effects of methyltestosterone on sex reversal in bluegill. Prog. Fish-Cult. 35(1):44-47.

CHILD, D. and R.T. OGLESBY
1970. Annotated bibliography of limnological and related literature dealing with the Finger Lakes region. Publ. No. 29, Cornell Water Resour. and Marine Sci. Cent. Ithaca, N.Y. 28 p.

CHILD, D., R.T. OGLESBY, and L.S. RAYMOND
1971. Land use data for the Finger Lakes region of New York State. Publ. No. 33, Cornell Water Resour. and Marine Sci. Cent. Ithaca, N.Y. 29 p.

CHILDERS, W.F. and G.W. BENNETT
1967. Hook-and-line yield of largemouth bass and redear x green sunfish hybrids in a one-acre pond. Prog. Fish-Cult. 29(1):27-35.

CHUNG, N.K.
1973. Investigation of use of gel material for mine sealing. Environ. Prot. Agency, Rep. EPA-R2-73-135. 67 p.

CHURCHILL, M.A. and W.R. NICHOLAS
1966. Effects of impoundments on water quality. Proc. Nat. Symp. on Qual. Stand. for Nat. Waters, pp. 71-84. Univ. of Mich., Ann Arbor, Mich.

CLAIR, W.F. and J.D. BECK
1969. Pittsburgh gives its water the air. Water and Waste Eng. 6(6):51-53.

CLARK, C.F.
1964. Bluegill control experiment in Hamler Lake, Ohio. Ohio Dep. of Nat. Resour., Publ. W-335. Columbus, Ohio. 4 p.

CLEMENS, H.P. and M. MARTIN
1952. Effectiveness of rotenone in pond reclamation. Trans. Amer. Fish. Soc. 82:166-177.

COLE, W. and V. EBERT
1968. Determination of effects on a fertilizer-induced plankton turbidity of 18 to 24 inches by Secchi disc readings on submerged aquatic plants. Completion Report D-1-3. Kans. For., Fish and Game Comm. 10 p.

COLLINS, V.G.
1970. Recent studies of bacterial pathogens of freshwater fish. J. Soc. Water Treat. Exam. 19:3-31.

COMES, R.D. and L.A. MORROW
1971. Control of waterlilies with dichlobenil. Weed Sci. 19(4):402-405.

COMMITTEE ON COMMERCE, U.S. SENATE
1972. The toxic substance control act of 1971 and amendment: detergents. 92nd Congr., 1st Sess. Serv. No. 92-50, U.S. Gov. Print. Off., Washington, D.C.

COMMITTEE ON GOVERNMENT OPERATIONS, U.S. HOUSE OF REPRESENTATIVES
1967. To save America's small lakes (water pollution control and abatement). House Rep. No. 594. U.S. Gov. Print. Off., Washington, D.C. 20 p.
1970a. Phosphates in detergents and the eutrophication of America's waters. 91st Congr., 1st Sess., U.S. Gov. Print. Off., Washington, D.C. 318 p.
1970b. Phosphates in detergents and the eutrophication of America's waters. 91st Congr., 2nd Sess., House Rep. No. 91-1004. U.S. Gov. Print. Off., Washington, D.C. 88 p.
1972. Phosphates and phosphates substitutes in detergents. 92nd Congr., 1st Sess. U.S. Gov. Print. Off., Washington, D.C.

CONVERY, J.J.
1970. Treatment techniques for removing phosphorus from municipal wastewaters. Water Pollut. Control Res. Ser. No. 17010-01/70. U.S. Gov. Print. Off., Washington, D.C. (No. 1970-389-930).

COOK, S.F., JR. and R.L. MOORE
1970. Mississippi silversides, *Menidia audens* (Atherinidae), established in California. Trans. Amer. Fish. Soc. 99(1):70-73.

COOKE, G.D. and R.L. KENNEDY
1970. Eutrophication of northeastern Ohio lakes. I. Introduction, morphometry, and certain physico-chemical data of Dollar Lake, Ohio. J. Sci. 70:150-161.

COOLEY, P.
1970. Wraysbury Reservoir: prevention of thermal stratification. Second Conf. in Water Qual. and Techol. Budapest, Hungary.

COOLEY, P., J.A. STEEL, and J.E. RIDLEY
1967. Impoundment destratification by mechanical pumping-discussion. Amer. Soc. Civ. Eng., Sani. Eng. Div. 93 (SA4):139-141.

COOPER, E.L., C.C. WAGNER, and G.E. KRANTZ
1971. Bluegills dominate production in a mixed population of fishes. Ecology 52(2):280-290.

COPE, O.B., J.P. McCRAREN, and L. ELLEN
1969. Effects of dichlobenil on two fishpond environments. Weed Sci., 17:158-165.

COREY, R.B., A.D. HASLER, G.F. LEE, F.H. SCHRAUFNAGEL, and T.L. WIRTH
1967. Excessive water fertilization. Rep. to the Water Subcomm., Nat. Resour. Comm. of State Agencies. Madison, Wis. 58 p.

CORNING, R.V. and N.S. PROSSER
1969. *Elodea* control in a potable water supply reservoir. Hyacinth Control. J. 8(1):7-12.

COTTAM, G. and S.A. NICHOLS
1970. Changes in water environment resulting from aquatic plant control. Tech. Rep. OWRR B-019-Wis., Univ. of Wis. Water Resour. Cent. Madison, Wis. 132 p.

COUCH, R.
1973. Response of aquatic weeds to laser radiation. Abstract No. 92. Conf. Weed Sci. Soc. of Amer.

COWELL, B.C.
1967. The effects of silvex on aquatic vegetation and plankton in central New York ponds. Down to Earth, 1965, 21 (1/2):19-20.

CRABTREE, J.E.
1967. Buffalo lake carp control. Job Completion Rep. Proj. No. F-14-D10, Job No. 16-a-53. Austin, Tex. 5 p.

CRANCE, J.L.
1963. The effects of copper sulfate on *Microcystis* and zooplankton in ponds. Prog. Fish-Cult. 25(4):198-202.

CRAWFORD, B.
1957. Report on the second fall and winter drawdown on Nimrod Lake–1956-1957. Arkansas Game and Fish Comm. Little Rock, Arkansas. 8 p.

CROUSE, W.A.
1941. An automatic weeding machine. Water Works Eng. 94:1054.

CZERNIN-CHUDENITZ, C.
1967. Seebelüftung zur Sauerstoffanreicherung [In German]. Österreichische Wasserwirtschaft 19 (5/6):98-105.

DAFT, M.J., J. BEGG, and W.D.P. STEWART
1970. A virus of blue-green algae from freshwater habitats in Scotland. New Phytol. 69:1029-1038.

DALY, R.W., H.H. FUNDERBURK, JR., and J.M. LAWRENCE
1968. Persistence of diquat, paraquat, and 2,4-DBEE when used for Eurasian watermilfoil *(Myriophyllum spicatum* L.) control. Proc. South. Weed Conf. 21:299.

DANIEL, T.C.
1971. Evaluation of diquat and endothall for the control of water milfoil and effect of weed kill on nitrogen and phosphorus status of a water body. Ph.D. Thesis, Univ. of Wis. Madison, Wis.

DANIELS, S.L. and D.G. PARKER
1973. Removing phosphorus from waste water. Environ. Sci. and Technol. 7(8):690-694.

DAVIS, J.F. and R.E. LUCAS
1959. Organic soils–their formation, distribution, utilization, and management. Mich. State Univ. Agric. Exp. Sta. Spec. Bull. 425.

DAVIS, J.T. and J.S. HUGHES
1964. The effect of summer drawdown on selected aquatic plants. Job Completion Rep., Wildl. and Fish. Comm. Baton Rouge, La. 2 p.
1968. Investigations of fish management practices in Bussey Lake. Completion Rep., Proj. F-7-R-8, La. Wildl. and Fish. Comm. Baton Rouge, La. 68 p.

DAVISON, V.E., J.M. LAWRENCE, and L.V. COMPTON
1962. Waterweed control on farms and ranches. Abstract. Proc. South. Weed Conf. 17:328.

DEAN, J.L.
1969. Biology of the crayfish *Orconectas causeyi* and its use for control of aquatic weeds in trout lakes. Bur. of Sport Fish. and Wildl., Tech. Pap. No. 24. 15 p.

DEQUINE, J.F.
1952. Florida's controlled seining program. Fish Manage. Bull. No. 1, Fla. Game and Fresh Water Fish Comm. Tallahassee, Fla. 39 p.

DERBY, R.L.
1956. Chlorination of deep reservoirs for taste and odor control. Amer. Water Works Assoc. 7:775-780.

DEUTSCHE FORSCHUNGSGEMEINSCHAFT
1968. Bodensee Projekt. Zweiter Bericht [In German]. Franz Steiner Verlag GMBH. Wiesbaden, West Germany. 166 p.

DEVICK, W.S.
1972. Limnological effects of artificial aeration in the Wahiawa Reservoir. Job Completion Rep., Proj. F-9-2, Job 2, Study IV. Honolulu, Hawaii

DICKMAN, M.
1969. Some effects of lake renewal on phytoplankton productivity and species composition. Limnol. and Oceanogr. 14:660-666.

DIETZ, E.M.C. and K.C. JURGENS
1963. An evaluation of selective shad control at Medina Lake, Texas. Tex. Parks and Wildl. Dep., IF Rep. Ser., No. 5. Austin, Tex. 32 p.

DIVISION OF SOIL CONSERVATION, DEPARTMENT OF CONSERVATION
1969. Sedimentation and erosion in the Upper Truckee River and Trout Creek watershed. Resour. Agency, State of Calif. 43 p.

DOMOGOLLA, B.P.
1926. Treatment of algae and weeds in lakes at Madison. Eng. News-Record 97(24):950-954.
1935. Eleven years of chemical treatment of the Madison lakes–its effect on fish and fish foods. Trans. Amer. Fish. Soc. 65:115-121.

DOMROSE, R.J.
1963. Aerator evalution. Mont. Fish and Game Dep., Job Completion Rep., Proj. F-12-R-9, Job III. 11 p.

DOWNING, E.P., J.E. HASSAN, and R.A. SWEENEY
1973. Annotated bibliography of Lake Ontario limnological and related studies–Vol. II–Biology. Environ. Prot. Agency, Ecol. Res. Ser., EPA-R3-73-028b. Washington, D.C. 236 p.

EARNEST, R.D.
1971. The effect of paraquat on fish in a Colorado farm pond. Prog. Fish-Cult. 33(1):27-31.

EAST TROY SANITARY DISTRICT NO. 1
1971. Sanitary district report: 1971 operations, Lake Beulah. East Troy, Wis. 5 p.

EDMONDSON, W.T.
1961. Changes in Lake Washington following an increase in the nutrient income. Verh. Int. Verein. Limnol. 14:167-175.
1966. Changes in the oxygen deficit of Lake Washington. Verh. Int. Verein. Limnol. 16:153-158.
1969. Eutrophication in North America, pp. 124-149. *In:* Eutrophication: Causes, Consequences, Correctives. Nat. Acad. of Sci., Washington, D.C.
1970. Phosphorus, nitrogen, and algae in Lake Washington after diversion of sewage. 169 (3946):690-691.
1972a. Nutrients and phytoplankton in Lake Washington. Nutrients and Eutrophication, Special Symposia, 1:172-193. Amer. Soc. of Limnol. and Oceanogr., Inc.
1972b. The present condition of Lake Washington. Verh. Internat. Verein. Limnol. 18:284-291.

EDMONDSON, W.T., G.C. ANDERSON, and D.R. PETERSON
1956. Artificial eutrophication of Lake Washington. Limnol. and Oceanogr. 1:47-53.

EHRLICH, S.
1969. Behavior of the nutria *(Myocastor coypus)*, with special regard to population density and its self-regulation. Ph.D. Thesis, Justus-Liebig Univ. Giessen, West Germany.

EICHER, G.J.
1947. Aniline dye in aquatic weed control. J. Wildl. Manage. 11:193-197.
1949. Localized weed control in management of game fish. Trans. Amer. Fish. Soc. 76:179-182.

ELIASSEN, R. and G. TCHOBANOGLOUS
1969. Removal of nitrogen and phosphorus from waste water. Environ. Sci. and Technol. 3:536-541.

EMERY, R.M.
1972. Initial responses by phytoplankton and related factors in Lake Sammamish following nutrient diversion. Ph.D. Thesis, Univ. of Wash. Seattle, Wash. 222 p.

EMERY, R.M., C.E. MOON, and E.B. WELCH
1971. Delayed recovery in a mesotrophic lake following nutrient diversion. Presented at the 38th Ann. Meet. of the Pac. Northwest Pollut. Control Assoc., Spokane, Wash. 29 p.
1972. Enriching effects of urban runoff on the productivity of a mesotrophic lake. Presented at the 20th Ann. Meet. of the Midwest Bentholog. Soc. Ames, Iowa. 22 p.
1973. Delayed recovery of a mesotrophic lake after nutrient diversion. Water Pollut. Control Fed. 45(5):913-925.

ENGINEERING NEWS–RECORD
1962. Fluff pump cleans clogged lake. 169(15):45.
1973. Dead and dying lakes are rescued by a dredge. May 24:18-19.

ENNIS, G.L.
1972. The effects of low nutrient water additions of summer phytoplankton diversity in a small eutrophic lake. B.S. Thesis, Univ. of B.C. Vancouver, British Columbia. 83 p.

ERICKSON, O.P.
1962. Latest dredging practice. Trans. Amer. Soc. Civ. Eng. 127:1-14.

ESCHMANN, K.H.
1969. Die Sanierung des Wilersees durch ableitung des tiefenwassers [In German]. Gesundheitstechnik 3(5):125-128.

EUNPU, F.F.
1971. Control of reservoir eutrophication by aeration. Presented at the Amer. Water Works Assoc. Meet. Arlington. Va. 23 p.

EVANS, R.L.
1954. Healing the sick: Neff Lake. Colo. Conserv. 3(1):27-30.

EVERETT, L.G.
[?] A mathematical model of primary productivity and limnological patterns in Lake Mead. Tech. Rep. No. 13, Hyd. and Water Resour., Univ. of Ariz. Tucson, Ariz.

FALCONER, A.C.
1970. Eutrophication and Lake McIlwaine. Rhod. Sci. News 4:52.

FARM POND HARVEST
1969. Wintertime haven. Fall issue.

FAST, A.W.
1968. Artificial destratification of El Capitan Reservoir by aeration. Part I. Effects on chemical and physical parameters. Calif. Dep. of Fish and Game, Fish Bull. 141.
1971a. The effects of artificial aeration on lake ecology. Environ. Prot. Agency, Water Pollut. Control Res. Ser. 16010 EXE 12/71. 470 p.
1971b. Effects of artificial destratification on zooplankton depth distribution. Trans. Amer. Fish. Soc. 100(2):355-358.
1973. Summertime artificial aeration increases winter oxygen levels in a Michigan lake. Prog. Fish-Cult. 35(2):82-84.

FAST, A.W. and J.A. ST. AMANT
1971. Nighttime artificial aeration of Puddingstone Reservoir, Los Angeles County, California. Calif. Fish and Game 57(3):213-216.

FINDENEGG, I.
1972. Das Phytoplankton des Reither Sees (Tirol, Österreich) im Jahre 1961. Ber. nat.-med. Ver. Innsbruck 59:15-24.

FINN, E.L., JR.
1972. Capitol Lake weed control and recommendations for 1973. Unpubl. rep. Wash. Dep. Fish. 2 p.

FISH, G.R.
1963. Observations on excessive weed growth in two lakes in New Zealand. N.Z. J. Bot. 1:410-418.

FITZGERALD, G.P.
1964. Algal blooms. Presented at N.A.T.C. Syracuse Univ., Adv. Stud. Inst. 10 p.
1965. Is the quality of our water deteriorating? Presented at the Int. Water Qual. Symp. Washington, D.C. 9 p.
1968. Detection of limiting or surplus nitrogen in algae and aquatic weeds. J. Phycol. 4:121-126.
1969a. Some factors in the competition or antagonism among bacteria, algae, and aquatic weeds. J. Phycol. 5:351-359.
1969b. Field and laboratory evaluations of bioassays for nitrogen and phosphorus with algae and aquatic weeds. Limnol. and Oceanogr. 14:206-212.
1970. Aerobic lake muds for the removal of phosphorus from lake waters. Limnol. and Oceanogr. 15(4):550-555.
1971. Algicides. Univ. Wis. Water Resour. Cent., Eutroph. Inf. Program, Lit. Rev. No. 2. Madison, Wis. 50 p.

FITZGERALD, G.P. and F. SKOOG
1954. Control of blue-green algae blooms with 2, 3-dichloro-

nophoquinone. Sewage and Ind. Wastes 26(9):1136-1140.

FLICK, W.
1968. Dispersal of aerated water as related to prevention of winterkill. Prog. Fish-Cult. 30(1):13-18.

FLORIDA DEPT. OF POLLUTION CONTROL
1972. Lake Apopka restoration project plan. Tallahassee, Fla. 225 p.

FLORIDA TECHNOLOGICAL UNIVERSITY AND ORANGE COUNTY POLLUTION CONTROL DEPT.
1972. Lake Eola restoration–phase II. Presented to the Public Works Dir., Orlando, Fla.

FOMIN, V.I. and H.D. BRUHN
[?] Dewatering and dewatering processes, bibliography Univ. of Wisconsin, College of Agric. and Life Sci., Res. Div. R2386. Madison, Wis.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
1968. Proc. World Symp. on Warmwater Pond Fish Cult. FAO Fish. Rep. No. 44, Vol. 5. Rome, Italy. 411 p.

FOREST, H.S. and E.L. MILLS
1971. The aquatic flora of Conesus Lake, Livingston Co., New York. Proc. Rochester Acad. Sci. 12:110-131.

FORSBERG, C. and Å. FORSBERG
1973. Utsläppskontroll vid kommunala reningsverk. Minitest. Vatten 2/73:173-176.

FORSBERG, C., B. HAWERMAN, and L. ULMGREN
1972. A programme for studies of the recovery of polluted lakes. Vatten 2:156-161.

FOX, A.C.
1968. Lake eutrophication problem and progress. Minutes of the 152nd Meet., Mo. Inter-Agency Comm., pp. F1-6. Bismarck, N.D.

FOYE, R.E.
1956. Reclamation of potential trout ponds in Maine. J. Wildl. Manage. 20(4):389-398.

FREDRICKSEN, R.L.
1970. Erosion and sedimentation following road construction and timber harvest on unstable soils in three small western Oregon watersheds. U.S. For. Serv., Res. Pap. 104, pp. 1-15.

FRINK, C.R.
1967. Nutrient budget: rational analysis of eutrophication in a Connecticut lake. Environ. Sci. and Technol. 1:425-428.

FROST, T.P.
1960. Practical algae control methods for New Hampshire water supplies. J.N.H. Water Works Assoc. 7 p.
1963. Observations and experience in the control of algae. J. N.H. Water Works Assoc. 6 p.

FRY, J.P. and W.D. HANSON
1968. Lake Taneycomo: a coldwater reservoir in Missouri. Trans. Amer. Fish Soc. 97:138-145.

GAHLER, A.R.
1969. Sediment-water nutrient interchange. Proc. Eutroph. Biostim. Assess. Workshop, pp. 243-257. Univ. Calif. Berkeley, Calif.

GAHLER, A.R., W.D. SANVILLE, J.A. SEARCY, C.F. POWERS, and W.E. MILLER
In prep. Studies on lake restoration by phosphorus inactivation. Environ. Prot. Agency, Nat. Eutroph. Prog. Corvallis, Oreg.

GAMMON, J.R. and A.D. HASLER
1965. Predation by introduced muskellunge on perch and bass, I: year 1-5. Wis. Acad. Sci., Arts and Lett. 54:249-272.

GANGSTAD, E.O.
1972. Herbicidal control of aquatic plants. Amer. Soc. Civ. Eng., Sani. Eng. Div. 98(SA2):397-406.

GERLOFF, G.C.
1969. Evaluating nutrient supplies for the growth of aquatic plants in natural waters, pp. 537-555. *In:* Eutrophication: causes, consequences, correctives. Nat. Acad. of Sci., Washington, D.C.

GERLOFF, G.C. and F. SKOOG
1954. Cell content of nitrogen and phosphorus as a measure of their availability for growth of *Microcystis aeruginosa.* Ecology 35(3):348-353.

GIBSON, B.
1971. Sediment removal saves aging Swedish lakes. Water and Pollut. Control 109(6):28-29.

GILBERT, C.E. and J.M. CORTELL
1970. Chemical control of *Potamogeton robbinsii* utilizing the submersed application technique. Proc. Northeast. Weed Sci. Soc. 24:287-289.

GILDERHUS, P.A., B.L. BERGER, and R.E. LENNON
1969. Field trials of antimycin A as a fish toxicant. U.S. Dep. Inter., Bur. of Sport Fish. and Wildl., Invest. in Fish Control No. 27. Washington, D.C. 21 p.

GILSON, H.C.
1962. Report of the director: operation "Swizzlestick." 30th Ann. Rep. Freshwater Biol. Assoc., Ambleside, Westmorland, G.B.

GIROUX, D.H.
1952. Modern hydraulic dredging–a product of experience. Civ. Eng., Sept.:156-161.

GLANCY, P.A.
1969. A mudflow in the Second Creek drainage, Lake Tahoe basin, Nevada, and its relation to sedimentation and urbanization. U.S. Geol. Surv., Prof. Pap. 65, pp. C195-C200.
1971. A reconnaissance of streamflow and fluvial sediment transport, Incline Village area, Lake Tahoe, Nevada, first progress report, 1970. Nev. Dep. of Conserv. and Nat. Resour., Water Res. Inf. Ser. Rep. 8. 28 p.

GODDARD, J.E. and H.F. SCHAEFER
Undated. In-situ clarification of ponds and reservoirs. The Dow Chem. Co. 11 p.

GOLDMAN, C.R.
1968. Limnological aspects of Clear Lake, California; with special reference to the proposed diversion of Eel River water through the lake. Rep. to the Fed. Water Pollut. Control Adm. Inst. of Ecol., Univ. of Calif., Davis, Calif. 16 p.
1970. Is the canary dying? Calif. Med. 113:21-26.
1972a. The role of minor nutrients in limiting the productivity of aquatic ecosystems. Nutrients and Eutroph., Spec. Symp. 1:21-38. Amer. Soc. of Limnol. and Oceanogr., Inc.
1972b. Environmental impact and water development. Amer. Water Works Assoc. 64(9):545-549.

GOLDMAN, C.R., H. MOSHIRI, and E. de AMAZAGA
1970. Synoptic study of accelerated eutrophication in Lake Tahoe–a sub-alpine lake. Presented at the Int. Symp. on Water Pollut. Control in Cold Clim. Univ. of Alaska, Alaska. 21 p.

GOLUEKE, C.G. and W.J. OSWALD
1965. Harvesting and processing sewage-grown planktonic algae. Water Pollut. Control Fed. 37:471-498.

GORIUSHYN, V.A. and S.M. CHAPLINSKAYA
1966. Existence of viruses of blue-green algae [In Russian, English summary]. Mikrobio. Zh. Akad Nauk. Ukr. RSR 28:94-97.

GOULDER, R.
1969. Interaction between the rates of production of freshwater macrophytes and phytoplankton in a pond. Oikos 20:300-309.

GOVERNMENTS OF CANADA AND THE UNITED STATES OF AMERICA
1972. Agreement between Canada and the United States of America on Great Lakes water quality. Ottawa, Ontario. 36 p.

GRANHALL, U.
1972. *Aphanizomenon flos-aqua;* infection by cyanophages. Physiol. Plant. 26:332-337.

GRANHALL, U. and A.V. HOFSTEN
1969. The ultra-structure of a cyanophage attack on *Anabaena variabilis.* Physiol. Plant. 22:713-722.

GREAT BRITAIN
1959. Water conservation and weed control. World Crops 11:375.

GREENBANK, J.
1941. Selective poisoning of fish. Trans. Amer. Fish. Soc. 70:80-86.
1945. Limnological conditions in ice-covered lakes, especially as related to winterkill of fish. Ecol. Monogr. 15(4):343-393.

GREESON, P.E.
1971. Limnology of Oneida Lake with emphasis on factors contributing to algal blooms. U.S. Geol. Surv., Open-file Rep. and N.Y. State Dep. of Environ. Conserv. Albany, N.Y. 185 p.

GREUNDLING, G.K. and A.C. MATHIESON
1969. Phytoplankton flora of Newfound and Winnesquam Lakes, New Hampshire. Rhodora 71:787.

GRICE, F.
1958. Effect of removal of panfish and trashfish by fyke nets upon fish populations of some Massachusetts ponds. Trans. Amer. Fish. Soc. 87:108-115.

GRIM, J.
1952. Ein see wird ungeflugt [In German]. Allegemeinen Fischerei-Zeitung 14(77):281-283.

GRIZZELL, R.A., JR.
1966. Diuron as an aquatic herbicide. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 19:194-197.

GUMERMAN, R.C.
1970. Aqueous phosphate and lake sediment interaction. Proc. Conf. Great Lakes Res. 13:673-682.

H.G. ACRES, LTD.
1971. Water quality methodology and its application to the Saint John River (11 vol.). Policy Plan. Dir., Dep. of the Environ. Ottawa, Ont.

HACKER, V.A.
1952. An analysis of Lake Kegonsa rough fish daily catch reports for the period 1937-1951. Wis. Conserv. Dep., Fish. Biol. Sect., Invest. Rep. No. 667. Madison, Wis. 29 p.

HAERTEL, L.
1972. Ecological factors influencing production of algae in northern prairie lakes. S.D. State Univ., Water Resour. Inst., Completion Rep., Proj. No. A-208-SDAK.

HAINES, B
1972. Destratification of lakes. Job Progress Report, Federal Aid Project F-22-R-12. N.M. Dep. of Game and Fish.

HALL, T.F., W.T. PENFOUND, and A.D. HESS
1946. Water level relationships of plants in the Tennessee Valley with particular reference to malaria control. J. Tenn. Acad. Sci. 21(1):18-59.

HALSEY, T.G.
1968. Autumnal and over-winter limnology of three small eutropnic lakes with particular reference to experimental circulation and trout mortality. Fish. Res. Bd. Can. 25(1):81-99.

HALSEY, T.G. and D.M. GALBRAITH
1971. Evaluation of two artificial circulation systems used to prevent trout winterkill in small lakes. B.C. Fish and Wildl. Br., Fish. Manage. Pub. 16.

HALSEY, T.G. and S.J. MacDONALD
1971. Experimental trout introduction and artificial circulation of Yellow Lake, British Columbia, B.C. Fish and Wildl. Br., Fish. Manage. Rep. 63.

HÄMÄLÄINEN, M.
1969. Happikadon torjunta alusveden vaihdolla [In Finnish]. Vesitalous 10(3):25-27.

HAMM, A.
1968. Bisherige untersuchungen an oberbayerischen. Seen im hinblick auf die auswirkeungen van seesanierungsmassnahmen [In German]. Wasser-und Abwasserforschung 4:135-141.
1971. Limnologische untersuchungen am Tegernsee und Schliersee nach der abwasserfernhaltung [In German]. WAF, Nr. 5/72.

HAMMER, U.T.
1972. Eutrophication and its alleviation in the Upper Qu'Appelle River system, Saskatchewan. Presented at the Symp. of Lakes of West. Can. Univ. of Alberta, Edmonton, Alberta. 24 p.

HARP, G.L. and R.S. CAMPBELL
1964. Effects of the herbicide silvex on benthos of a farm pond. J. Wildl. Manage. 28(2):308-317.

HARRISON, J.S.
1961. Rehabilitation of Lake Maloya and its watershed. N.M. Dep. of Game and Fish, Job Completion Rep., Proj. F-19-D-3. Sante Fe, N.M. 7 p.

HARTER, R.D.
1968. Adsorption of phosphorus by lake sediment. Proc. Soil Soc. Amer. 32(4):514-518.

HASKELL, W.L.
1955. Carp elimination at Mittry Lake. Ariz. Game and Fish Dep., Wildl. Restoration Div. Spec. Rep., Project W-67-D-3. Phoenix, Arizona, 9 p.

HASLER, A.D.
1973. Poisons, phosphates, preservation, people and politics—a fish eye's view of ecology. Trans. Amer. Fish. Soc. 102(1):213-224.

HASLER, A.D. and E. JONES
1949. Demonstration of the antagonistic action of large aquatic plants on algae and rotifers. Ecology 30:359-364.

HAWKES, R.B.
1965. Domestic phases of programs designed to use insects to suppress alligator weed. Proc. South. Weed Conf. 18:584-585.

HAYES, F.R. and D.A. LIVINGSTONE
1955. The trout population of a Nova Scotia lake as affected by habitable water, poisoning of the shallows and stocking. Fish. Res. Bd. Can. 12(4):618-635.

HAYNES, R.C.
1971. Some ecological effects of artificial circulation on a small eutrophic New Hampshire lake. Ph.D. Thesis, Univ. of N.H. Durham, N.H. 166 p.
In press. Some ecological effects of artificial circulation on a small eutrophic lake with particular emphasis on phytoplankton. I. Kezar Lake experiment, 1968. Hydrobiologia.

HELM, W.J.
1951. An interpretation of rough fish statistics from Lake Waubesa. Wis. Conserv. Dep. Invest. Rep. No. 751. Madison, Wis. 21 p. (mimeo).

HELMS, D.R.
1967. Experimental use of antimycin A to control spawning carp in Backbone Lake. Iowa Conserv. Comm., Des Moines, Iowa. 2 p.

HEMAN, M.L.
1965. Manipulation of fish populations through reservoir drawdown, with emphasis on *Micropterus salmoides* (Lacepeded). M.A. Thesis, Univ. of Mo. 65 p.

HEMAN, M.L., R.S. CAMPBELL, and L.C. REDMOND
1969. Manipulation of fish populations through reservoir drawdown. Trans. Amer. Fish. Soc. 98(2):293-304.

HEMPHILL, J.F.
1954. Toxaphene as a fish toxin. Prog. Fish-Cult. 16(1):41-42.
1955. A method of winterkill prevention. Fish Div., Ariz. Game and Fish Dep.

HENEGAR, D.L.
1958. A summary of eight years of chemical fish control in North Dakota. N.D. State Game and Fish Dep., Bismarck, N.D. 9 p.
1966. Minimum lethal levels of toxaphene as a piscicide in North Dakota lakes. U.S. Dep. of the Inter., Bur. of Sport Fish. and Wildl., Resour. Publ. 7. Washington, D.C. 16 p.

HERBICH, J.B. and R.H. SNIDER
1969. Bibliography on dredging. Texas A & M Univ., Sea Grant Publ. 203.

HILTIBRAN, R.C.
1963. Effects of endothall on aquatic plants. Weeds 11:256-257.
1965. Effects of diquat on aquatic plants in central Illinois. Weeds 13:71-72.
1967. Eradication of curlyleaf pondweed from Mansion Pond. Presented at the Ann. Meet. Weed Sci. Soc. of Amer. Washington, D.C.
1968. Aquatic weed control in Illinois. Hyacinth Control J. 7:11-13.

HINMAN, H.F.
1969. Sanitary survey report—Grand Lake, Shadow Mt. Lake and Lake Granby. Colo. Dep. of Health, Denver, Colo.

HOFFMAN, D.A. and R.C. PAYNETTE
1956. "Operation carp" on a San Diego reservoir. Water and Sewage Works 103(7):281-287.

HOLCOMB, D.E. and W. WEGENER
1971. Hydrophytic changes related to lake fluctuation as measured by point transects. Proc. Southeast. Assoc. of Game and Fish Comm.

HOLTAN, H.
1972. Gjersjoen—a eutrophic lake in Norway. Verh. Internat. Verein. Limnol. 18:349-354.

HOOPER, A.D. and J.H. CRANCE
1960. Use of rotenone in restoring balance to overcrowded fish populations in Alabama lakes. Trans. Amer. Fish Soc. 89:351-357.

HOOPER, F.F. and K.G. FUKANO
1960. Summary of experimental lake treatments with toxaphene 1954-1958. Mich. Dep. of Conserv., Rep. No. 1584. Ann Arbor, Mich. 17 p.

HOOPER, F.F., R.C. BALL, and H.A. TANNER
1952. An experiment in the artificial circulation of a small Michigan lake. Trans. Amer. Fish. Soc. 82:222-241.

HOOPER, F.F., J.E. WILLIAMS, M.H. PATRIARCHE, F. KENT, and J.C. SCHNIEDER
1964. Mich. Dep. Conserv., Inst. Fish. Res., Rep. No. 1688. Ann Arbor, Mich. 56 p.

HORNE, A.J.
1972. Control of blue-green nuisance blooms—the effects of nitrogen fixation, aeration/mixing and related parameters. Clear Lake Algal Res. Unit, 2nd Ann. Rep. Lakeport, Calif.

HORTON, M.A.
1972. The chemistry of P in Lake Sammamish. M.S. Thesis, Univ. of Wash.

HOUSER, A. and B. GRINSTEAD
1961. The effect of black bullhead catfish and bluegill removal on the fish population of a small lake. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 15:193-200.

HOWARD, R.G.
1972. Reservoir destratification improves water quality. Reclamation Era. A Water Rev. Q. Feb.:6-7.

HUBAULT, E.
1947. Etudes thermiques, chimiques et biologiques des eaux des lacs de l'est de la France (Vosges—Jura—Alpes de Savoie). Annales de l'Ecole Nationale des Eaux et Forets 10:115-260.

HUBBS, C.L. and R.W. ESCHMEYER
1938. The improvement of lakes for fishing. Univ. of Mich., Inst. Fish. Res., Bull. No. 2. Ann Arbor, Mich. 233 p.

HUGHES, R.A.
1968. The persistence of toxaphene in natural waters. M.S. Thesis, Water Chem., Univ. of Wis. Madison, Wis. 136 p.

HUISH, M.T.
1957. Gizzard shad removal in Deer Island Lake, Florida. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 11:312-318.

HULSEY, A.H.
1956. Effects of a fall and winter drawdown on a flood control lake. Presented at the 5th Ann. Meet. of the South Div. of the Amer. Fish. Soc. Little Rock, Arkansas.

HULSEY, A.H. and J. STEVENSON
1959. Reclamation of Lake Hamilton, Arkansas. Prog. Fish-Cult. 21(2):70-74.

HUSTON, J.E.
1956. Experimental field applications of calcium carbide pellets. Q. Rep., Colo. Fish. Res. Unit 2(3 and 4):2-5.

HUTCHINSON, G.E.
1973. Eutrophication. Amer. Sci. 61(3):269-279.

HYNES, H.B.N. and B.J. GREIB
1967. Experiments on control of release of phosphate from lake muds. Great Lakes Res. Div., Univ. of Mich. 16:357.
1970. Movement of phosphate and other ions from and through lake muds. Fish. Res. Bd. Can. 27(4):653-668.

INDUSTRIAL WATER ENGINEERING
1966. Water treatment with compressed air. 3:40-41.

INLAND FISHERIES BRANCH
1970. Effects of artificial destratification on distribution of bottom organisms in El Capitan Reservoir. Calif. Dep. of Fish and Game, Fish. Bull. 148.

INLAND FISHERIES TRUST, INC.
1972. Report on waters in which there are actual or potential pollution and/or eutrophication problems. Mobhi Boreen, Galsnevin, Dublin, Ireland. 16 p.

INST. F. SIEDLUNGSWASSERWIRTSCHAFT, TECHNISCHE UNIV. HANNOVER
1970. Die Belastung des Dümmer mit sauerstoffzehrenden und düngenden Stoffen. Hannover, West Germany.

INSTITUTO DE INGENIERÍA
To be published. Estudio Limnologico del Lago de Chapala. Presented to the Ministry of Water Resources, Universidad Nacional Autónoma de México.

INTERNATIONAL JOINT COMMISSION, CANADA AND THE UNITED STATES
1970. Pollution of Lake Erie, Lake Ontario and the international section of the St. Lawrence River. Rep. U.S. Dep. State, Washington, D.C. 174 p.

IRWIN, W.H., J.M. SYMONS, and G.G. ROBECK
1966. Impoundment destratification by mechanical pumping. Amer. Soc. Civ. Eng., Sanit. Eng. Div. 92(SA6):21-40.
1967. Water quality in impoundments and modifications from destratification. *In:* Symons, J.M. (ed.). Water quality behavior in reservoirs. Public Health Serv. Publ. No. 1930. Cincinnati, Ohio.

ISAAC, G.W., R.I. MATSUDA, and J.R. WELKER
1966. A limnological investigation of water quality conditions in Lake Sammamish. Munc. METRO, Water Qual. Ser. No. 2. Seattle, Wash. 47 p.

JACKSON, C.F.
1956. Control of the common sunfish or pumpkinseed, *Lepomis gibbosus* in New Hampshire. Tech. Circ. No. 12, N.H. Fish and Game Dep. 16 p.
1962. Use of chlorine for reclaiming ponds. N.H. Dep. of Fish and Game, Job Completion Rep., Proj. FW-2-R-9. 7 p.

JACKSON, S.W., JR.
1966. Summary of fishery management activities on lakes Eucha and Spavinaw, Oklahoma. Proc. Ann. Conf. Southeast. Assoc. Game Comm. 19:315-343.

JAPANESE ASSOCIATION OF CIVIL ENGINEERS
1969. On the future pollution of Lake Biwa. Ann. Rep., Sanit. Eng. Div.
1970. On the future pollution of Lake Biwa. Ann. Rep., Sanit. Eng. Div.
1971. On the future pollution of Lake Biwa. Ann. Rep., Sanit. Eng. Div.

JASON M. CORTELL AND ASSOC.
1973. Final report: improving water quality and controlling algae in eutrophic lakes. Consultant's Rep. Wellesley Hills, Mass.

JAWORSKI, N.A. and L.J. HETLING
1970. Relative contributions of nutrients to the Potomac River basin from various sources. U.S. Dep. Inter., Fed. Water Pollut. Control Adm., Middle Atl. Reg. Tech. Rep. No. 31. 36p.

JENKINS, D., F. FERGUSON, and B. MENAR
1971. Chemical processes for phosphate removal. Water Res. 5(7):369-389.

JENKINS, R.M.
1955. Expansion of the crappie population in Ardmore City Lake following a drastic reduction in numbers. Proc. Okla. Acad. Sci. 36:70-76.
1956. Some results of the partial fish population removal techniques in lake management. Proc. Okla. Acad. Sci. 37:164-173.
1970a. The influence of engineering design and operation and other environmental factors on reservoir fishery resources. Water Res. Bull. 6:110-119.
1970b. Reservoir fish management; pp. 173-182. *In:* A century of fisheries in North America. Amer. Fish. Soc. Spec. Publ. No. 7. Washington, D.C.

JERBO, A.
1973. Two types of oil spills in Swedish inland waters—tests of new materials, ideas, and methods. Proc. Jt. Conf. on Prev. and Control of Oil Spills, pp. 559-567. Washington, D.C.

JERNELÖV, A.
1970. Phosphate reduction in lakes by precipitation with aluminum sulphate. Water Pollut. Res. Conf. Stockholm, Sweden.

JOHNSON, M.G. and A.H. BERST
1965. The effect of low-level discharge on the summer temperature and oxygen content of a southern Ontario reservoir. Can. Fish Cult. 35:59-66.

JOHNSON, P., H. MATHIESEN, and U. RØEN
1962. The Sorø-lakes lake Lyngby Sø and lake Bagsvaerd Sø. Limnological studies on five culturally influenced lakes in

Sjaelland (Zealand) [In Danish, English summary]. Dansk Ingeniørforeining Spildevandeskomitteen, 14:1-135.

JOHNSON, R.C.
1966. The effect of artificial circulation on production of a thermally stratified lake. Wash. Dep. Fish. Res. Pap. 2(4):5-15.

JOHNSON, R.E.
1948. Maintenance of natural population balance. Proc. Conf. Int. Assoc. Game Fish and Conserv. Comm. 38:35-42.

JOHNSON, W.C.
1966. Toxaphene treatment of Big Bear Lake, California. Calif. Fish and Game 52(3):173-179.

JUNOR, F.J.R.
1969. *Tilapia melanopheura* Dum., in artificial lakes and dams in Rhodesia with special reference to its undesirable effects. Rhod. J. Agric. Res. 7:61-69.

KAJAK, Z., K. DUSOGE, A. HILLBRICHT-ILKOWSKA, E. PIECZYNSKI, A. PREJS, I. SPODNIEWSKA, and T. WEGLENSKA
1972. Influence of the artificially increased fish stock on the lake biocenosis. Verh. Internat. Verein. Limnol. 18:228-235.

KANDIYOHI COUNTY BOARD OF COMMISSIONERS
1971. Eagle Lake watershed research structures: project measure work plan. Wes Min RC and D Proj. Minn., Soil Conserv. Serv., U.S. Dep. of Agric. St. Paul, Minn. 30 p.

KARLGREN, L. and O. LINDGREN
1963. Luftningsstudier: Trasksjön [In Swedish]. Vattenhygien 3:67-79.

KATZER, M.F. and J.W. POLLACK
1968. Clarifying muddy waters, its possible with automatic system. Environ. Sci. and Technol. 2:341-352.

KEATING, J.F.
1961. Experimental rough fish control. Completion Rep., Proj. F-22-R-6. Idaho Dep. of Fish and Game. 7 p.

KEENEY, D.R.
1972. The fate of nitrogen in aquatic ecosystems. Univ. of Wis. Water Resour. Cent., Eutroph. Inf. Program, Lit. Rev. No. 3. Madison, Wis.
1973. The nitrogen cycle in sediment-water systems. J. Environ. Qual. 2(1):15-29.

KEENEY, D.R. and M.A. BRYANS
1972. Mobility of nitrogen in de-watered sediments. Rep. to the Inland Lake Demonstr. Proj., Upper Great Lakes Reg. Comm. Madison, Wis.

KENNEDY, M. and P. FITZMAURICE
1971. Growth and food of brown trout *Salmo trutta* L. in Irish waters. Proc. R. Ir. Acad. 71 B:269-352.

KERNEN, L.T.
1967. King-size conversion. Wis. Conserv. Bull., May-June issue.

KETELLE, M.J. and P.D. UTTORMARK
1971. Problem lakes in the United States. Univ. of Wis. Water Resour. Cent., Madison, Wis. 282 p.

KETO, J. and P. SEPPÄNEN
1974. Lake Tuusula oxidation test, winter 1972/1973. Aqua Fennica.

KIEFER, W.
1968. Pfanzen biologische Reinigung van Abwasser [In German]. Umschau (7):210.

KILBURN, R.W.
1971. Lake Wales, Florida. Method for controlling the growth of algae. U.S. Pat. No. 3,561,945 (Feb. 9).

KILLIAN, J.L.
1953. Rough fish control in San Carlos and Lakeside lakes. Ariz. Game and Fish Comm., Wildl. Restoration Div., Completion Rep., Proj. F-1-R-1. Phoenix, Ariz. 5 p.

KING, D.L.
1970. Reaeration of streams and reservoirs analysis and bibliography. REC-OCE 70-55 (NTIS PB 197 954). Bur. of Reclam., Denver, Colo.

KING, J.E.
1953. Growth rates of fishes of Lake Hiwassee, Oklahoma, after two years of attempted population control. Proc. Okla. Acad. Sci. 34:53-56.
1954. Three years of partial fish population removal at Lake Hiwassee, Oklahoma, Proc. Okla. Acad. Sci. 35:21-24.

KLASSEN, E.H., G. REMPEL, and A.R. PICK
1970. Pilot studies for quality management in terminal reservoir. Amer. Water Works Assoc. 62:555-560.

KLEINSCHMIDT, H.E.
1969. Effect of granular 2,4-D on some water weeds and its persistence. Queensland, J. Agric. Anim. Sci. 26(4):587-592.

KLINGBIEL, J., L. STRICKER, and O. RONGSTAD
1968. Wisconsin farm fish ponds. Univ. of Wis. Ext. Man. No. 2. 45 p.

KNOPPERT, P.L., J.J. ROOK, T. HOFKER, and G. OSKAM
1970. Destratification experiments at Rotterdam. Amer. Water Works Assoc. 62:448-454.

KOBERG, G.E. and M.E. FORD
1965. Elimination of thermal stratification in reservoirs and the resulting benefits. U.S. Geol. Surv., Water-Supply Pap. 1809-M.

KOCUROVA, E.
1966. The application of the algacide CA 350 in the Lubi reservoir near Tubic, Czechoslovakia. Hydrobiologia 28(2):223-240.

KOEGEL, R.G., H.D. BRUHN, and D.L. LIVERMORE
1972. Improving surface water conditions through control and disposal of aquatic vegetation. Tech. Rep. OWRR B-018-Wis., Univ. of Wis. Water Resour. Cent. Madison, Wis. 45 p.

KOLBE, F.F.
1964. Artificial oxygen regeneration at Goreangab Dam. Die Siviele Ingenieur in Suid-Afrika 6(1):5-8.

KŌ-SHIN-ETSU BRANCH OF THE JAPANESE SOCIETY OF LIMNOLOGY
1970. The quality and biotic community of the water in lake Shirakaba in a popular pleasure resort in the central plateau of Japan. I. Qualities of water and bottom mud [In Japanese; English summary]. The Jap. J. of Limnol. 31:(4):153-165.
1971. The quality and biotic community of the water in lake Shirakaba in a popular pleasure resort in the central plateau of Japan. II. Biotic community [In Japanese; English summary]. The Jap. J. of Limnol. 32(1):15-25.

KOTHANDARAMAN, V. and R.L. EVANS
1972. Removal of algae from waste stabilization pond effluents—a state of the art. Ill. State Water Surv., Circ. 108.

KREIL, A.
1969. Air aqua system research in Rolette County. N.D. State Game and Fish Dep., Proj. F-2-R-15, Job 8, Rep. A-1009.
1971. Air aqua system research in Rolette County. N.D. State Game and Fish Dep., Proj. F-2-R-17, Job 8, Rep. A-1015.

KUMAR, J. and J.A. JEDLICKA
1973. Selecting and installing synthetic pond linings. Chem. Eng., Feb. 5:67-70.

KUSLER, J.A.
1970. Water quality protection for inland lakes in Wisconsin: a comprehensive approach to water pollution. Wis. Law Rev. 1970, pp. 35-78.

LACKEY, R.T.
1971. Effects of artificial destratification of a lake ecosystem. Colo. Div. Game, Fish and Parks, Dingell-Johnson Rep. No. 2. 71 p.
1972a. A technique for eliminating thermal stratification in lakes. Water Res. Bull 8(1):46-49.
1972b. Response of physical and chemical parameters to eliminating thermal stratification in a reservoir. Water Res. Bull. 8(3):589.
1973. Artificial reservoir destratification effects on phytoplankton. Water Pollut. Control Fed. 45(4):668-673.

LACKEY, R.T. and D.W. HOLMES
1972. Evaluation of two methods of aeration to prevent winterkill. Prog. Fish-Cult. 34(3):175-178.

LAIDLAW, R.G.
1972. Chubb Lake rehabilitation. B.C. Fish and Wildl. Br., M.S. 8 p.

LAKE TAHOE AREA COUNCIL
1970. Eutrophication of surface waters—Lake Tahoe. Third Prog. Rep. (FWQA Grant No. 16010 DSW). South Lake Tahoe, Calif. 109 p.
1971. Eutrophication of surface waters—Lake Tahoe Indian Creek Reservoir. Environ. Prot. Agency, 16010 DNY 07/71.

LAMBOU, V.W. and H. STERN, JR.
1958. Preliminary report on the effects of the removal of rough fishes on the Clear Lake sport fishery. Proc. Southeast. Assoc. Game and Fish Comm. 12:36-56.

LANGE, S.R.
1965. The control of aquatic plants by commercial harvesting, processing and marketing. Proc. South. Weed Conf. 18:536-542.

LANTZ, K.E., J.T. DAVIS, J.S. HUGHES, and H.E. SCHAFER, JR.
1964. Water level fluctuation–its effect on vegetation control and fish population management. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 18:483-494.

LAST, D.G.
1971. The Lake Mendota watershed project. *In:* Natl. Symp. Anim. Waste Manage., Proc. Counc. State Gov. Environ. Prot. Agency, U.S. Dep. Agric., and others. Washington, D.C.

LATTERELL, J.J., R.F. HOLT, and D.R. TIMMONS
1971. Phosphate availability in lake sediments. J. Soil and Water Conserv., Jan.-Feb.:21-24.

LAURENT, P.J.
1969. Etude de la pollution de lac du Bourget, campagne 1969. Station d'Hydrobiologie Lacustre, Thonon-les-Baines, France, 15 p. (mimeo).

LAURENT, P.J., J. GARANCHER, and P. VIVIER
1970. The condition of lakes and ponds in relation to the carrying out of treatment measures. Presented at the 5th Int. Water Pollut. Res. Conf. 10 p.

LAVERTY, G.L. and H.L. NIELSEN
1970. Quality improvements by reservoir aeration. Amer. Water Works Assoc. 62(11):711-714.

LAWLER, G.H.
1961. Heming Lake experiment. Fish. Res. Bd. of Can., Prog. Rep. of the Biol. Sta. and the Technol. Unit 2:48-50.

LAWRENCE, J.M.
[?] Aquatic weed control in fish ponds. Auburn Univ., Agric. Exp. Sta. Auburn, Ala.
1958. Recent investigations on the use of sodium arsenite as on algacide and its effects on fish production in ponds. Proc. Ann. Conf. Southeast. Assoc. of Game and Fish Comm. 11:281-287.

LAWTON, G.W.
1961. Limitation of nutrients as a step in ecological control, pp. 108-117. *In:* Algae and metropolitan wastes. Robert A. Taft Eng. Cent. Tech. Rep. W61-3. Cincinnati, Ohio.

LEACH, L.E.
1968. Eufaula Reservoir aeration research. Proc. Okla. Acad. Sci. 49:174-181.

LEACH, L.E. and C.C. HARLIN, JR.
1970. Induced aeration of small mountain lakes. Environ. Prot. Agency, Water Pollut. Control Res. Rep. 16080-11/70.

LEACH, L.E., W.R. DUFFER, and C.C. HARLIN, JR.
1968. Pilot study of dynamics of reservoir destratification. Robert S. Kerr Water Res. Cent., Ada, Okla. 24 p.
1970. Induced hypolimnion aeration for water quality improvement of power releases. Environ. Prot. Agency, Water Pollut. Control Ser., 16080. Ada, Okla. 32 p.

LEE, G.F.
1970a. Eutrophication. Univ. of Wis. Water Resour. Cent. Lit. Rev. No. 2. Madison, Wis. 39 p.
1970b. An approach to the assessment of the role of phosphorus in eutrophication. Presented before the Div. of Water, Air, and Waste Chem., Amer. Chem. Soc. Los Angeles, Calif.
1970c. Factors affecting the transfer of materials between water and the sediments. Univ. of Wis. Water Resour. Cent., Eutroph. Inf. Prog., Lit. Rev. No. 1. Madison, Wis.
1972. Phosphorus, water quality and eutrophication of Lake Michigan. Presented at the Lake Mich. Enforcement Conf. 32 p.

LENNON, R.E. and B.L. BERGER
1970. A resume on field applications of antimycin A to control fish. U.S. Dep. of the Inter., Bur. of Sport Fish. and Wildl., Invest. in Fish Control No. 40. Washington, D.C. 19 p.

LENNON, R.E., J.B. HUNN, R.A. SCHNICK, and R.M. BURRESS
1970. Reclamation of ponds, lakes and streams with fish toxicants: a review. FAO Fisheries Tech. Paper No. 100, Food and Agriculture Organization of the United Nations. Rome, Italy. Reprinted by the U.S. Dep. Inter., Bur. of Sport Fish. and Wildl. Washington, D.C. 99 p.

LEOPOLD, L.B.
1968. Hydrology for urban land planning–a guidebook on the hydrologic effects of urban land use. U.S. Geol. Surv. Circ. 554 18 p.
1973. River channel change with time: an example. Geol. Soc. Amer. Bull. 84(6):1845-1860.

LIEBMANN, H.
1965a. Nährstaffanreicherung der gewässer durch häusliche und industrielle äbwasser, beschrieben am beispiel des Bodensees [In German]. Muncher Beitrage zur Abwasser–, Fischerei– und Flussbiologie 12:84-102.
1965b. Massnahmen zur sanierung des Schliersees und des Spitzingsees [In German]. Munchner Beitrage zur Abwasser–, Fischerei– und Flussbiologie 12: 139-148.
1970. Biological and chemical investigations on the effect of sewage on the eutrophication of Bavarian lakes. Presented at the 5th Int. Water Pollut. Res. Conf. San Francisco, Calif. 7 p.

LIEPOLT, R.
1957. Die Verunreinigung des Zellersees. Schriftenreihe Wasser und Abwasser 1957:9-38.
1958. Zur limnologischen Erforschung des Zellersees in Salzburg. Schriftenreihe Wasser und Abwasser 1958:18-101.
1967. Die limnologischen Verhältnisse des Zellersees, seine Verunreinigung und Reinigung.–Förd. Europ. Gewässerschutz, Inform. Bl. Nr. 14, 59-62.

LIKENS, G.E., F.H. BORMANN, N.M. JOHNSON, D.W. FISHER, and R.S. PIERCE
1970. Effects of forest cutting and herbicide treatment on nutrient budgets in the Hubbard Brook watershed ecosystem. Ecol Monogr. 40(1):23-47.

LIMNOS, THE GREAT LAKES ENVIRONMENTAL PROTECTION MAGAZINE
1972. The situation lake by lake (the Great Lakes). 5:19-23.

LIN, C., S.K. BHAGAT, and J.F. ORSBORN
1972. Simulation of water quality enhancement in a polluted lake. Eng. Ext. Serv., Bull. 324. Wash. State Univ., Pullman, Wash. 120 p.

LIND, C.T. and G. COTTAM
1969. The submerged aquatics of University Bay: a study in eutrophication. The Amer. Midl. Nat. 81:353-369.

LINDER, C.H. and P. MERCIER
1954. Etude comparative de la repartition du zooplankton au Lac de Bret avant et apres raeration [In French]. Schweiz. Zeit. Hydrol. 16(z):309-317.

LITTLE E.C.S.
1968. Handbook of utilization of aquatic plants. Food and Agric. Organ. of the U.N. Rome, Italy. 123 p.

LITTLE R.G.
1961. Rehabilitation of Bonito Lake and Bonito Creek. Job Completion Rep., Proj. F-19-D-3, N.M. Dep. Fish and Game. 7 p.

LIVERMORE, D.F. and W.E. WUNDERLICH
1969. Mechanical removal of organic production from waterways, pp. 494-519. *In:* Eutrophication: causes, consequences, correctives. Nat. Acad. of Sci. Washington, D.C.

LIVINGSTON, D.A. and J.C. BOYKIN
1962. Vertical distribution of phosphorus in Linsley Pond mud. Limnol. and Oceanogr. 7:48-56.

LOEHR, R.C. (ed.)
1972. Agric. Waste Manage. Conf., Proc. Coll. of Agric. and Life Sci., Cornell Univ. Ithaca, N.Y. 580 p.

LOMAX, C.C. and J.F. ORSBORN
1971. Flushing of small shallow lakes. Environ. Prot. Agency, Water Pollut. Control Res. Ser., 16010 DMG. Washington, D.C. 39 p.

LOND, H.Y.
1969. Optimum operation of microstrainers. Water Treat. Exam. 18(3):229-32.

LUESCHOW, L.A.
1972. Biology and control of selected aquatic nuisances in recreational waters. Dep. of Nat. Resour. Tech. Bull. No. 57. Madison, Wis. 36 p.

LUND, J.W.G.
1971. The seasonal periodicity of three planktonic desmids in Windermere. Mitt. Int. Ver. Limnol. 19:3-25.

MacBETH, S.E.
1973. Some observations on changes in water chemistry and algal

growth in artificial destratified lakes in Ontario. Presented at the 36th Ann. Meet. of the Amer. Soc. of Limnol. and Oceanogr. Salt Lake City, Utah.

MACKENTHUN, K.M.
1969. The practice of water pollution biology. Fed. Water Pollut. Control Adm., Washington, D.C. 281 p.

MACKENTHUN, K.M., W.M. INGRAM, and R. PORGES
1964. Limnological aspects of recreational lakes. Public Health Serv. Publ. No. 1167. Cincinnati, Ohio. 176 p.

MALUEG, K. W., J. TILSTRA, D. W. SCHULTS, and C. F. POWERS
1971. The effect of induced aeration upon stratification and eutrophication processes in an Oregon farm pond. Presented at the Int. Symp. Man-Made Lakes. Knoxville, Tenn.

MALUEG, K.W., R.M. BRICE, D.W. SCHULTS, and D.P. LARSEN
1973. The Shagawa Lake project. Lake restoration by nutrient removal from wastewater effluent. Environ. Prot. Agency, Ecol. Res. Ser., EPA-R3-73-026. Corvallis, Oreg. 49 p.

MARSHALL, B.E.
1970. The ecology of the bottom fauna of Lake McIlwaine. Rhod. Sci. News 4:53.

MARSHALL, B.E. and A.C. FALCONER
In press a. Physiochemical aspects of Lake McIlwaine, Rhodesia, a eutrophic tropical impoundment. Hydrobiologia.
In press b. Eutrophication of a tropical African impoundment (Lake McIlwaine, Rhodesia). Hydrobiologia.

MARSHALL, B.E. and D.S. MITCHELL
In press. Hydrobiological observations on three Rhodesian reservoirs. Freshwater Biol.

MATHEWS, R.A. and C. SCHWARY
1969. Preliminary bibliography, Lake Tahoe basin, Calif.-Nev. Coop Rep.: Res. Agency, Dep. of Conserv., Div. Mines and Geol., State of Calif. and Pac. Southwest. For. and Range Exp. Sta., U.S. Dep. Agric. Spec. Publ. 36. Berkeley, Calif. 102 p.

MATHIESEN, H.
1971. Summer maxima of algae and eutrophication. Mitt. Inter. Verein. Limnol. 19:161-181.

MATHIS, W.P.
1965. Observations on control of vegetation in Lake Catherine using Israeli carp and a fall and winter drawdown. Proc. Ann. Conf. Southeast. Assoc. Comm. 19:197-205.

MATHIS, W.P. and A. HULSEY
1959. Rough fish removal from Lake Catherine, Arkansas. Proc. Annu. Conf. Southeast. Assoc. Game and Fish Comm. 13:197-203.

MAYHEW, J.K. and S.T. RUNKEL
1962. The control of nuisance aquatic vegetation with black polyethylene plastic. Proc. Iowa Acad. Sci. 69:302-307.

McCARTER, J.A., F.R. HAYES, L.H. JODREY, and M.L. CAMERON
1952. Movement of materials in the hypolimnion of a lake studied by the addition of radioactive phosphorus. Can. J. Zool. 30:128-133.

McCULLOUGH, J. R.
1971. Keep that stored water fresh and make all of the water in the reservoir potable. Amer. City Mag. 86(4):63-65.

McDONALD, M.E.
1955. Cause and effect of a die-off of emergent vegetation. J. Wildl. Manage. 19:24-35.

McDONALD, R.A.
Undated. Use of a polyelectrolyte to reduce soil turbidity in two fish ponds and effects on plankton, benthos and fishery. Nebr. Game and Parks Comm., Hastings, Nebr. 34 p. (mimeo).

McGILL, S.M.
1969. The ecology of the phytoplankton of a new reservoir in the Thames Valley, Ph.D. Thesis, Univ. of London.

McHUGH, R.A.
1972. An interim study of some physical chemical, and biological properties of selected Oregon lakes. Dep. of Environ. Qual., Portland, Oreg. 123 p.

McNABB, C.D. and D.P. TIERNEY
1972. Growth and mineral accumulation of submersed vascular hydrophytes in pleioeutrophic environs. Tech. Rep. No. 26. Inst. of Water Res., Mich. State Univ. East Lansing, Mich. 32 p.

McNALL, W.J.
1971. Destratification of lakes. Job Progress Report, Project F-22-R-11. N.M. Dep. of Game and Fish. 31 p.

MEGARD, R.O.
1971. Eutrophication and the phosphorus balance of lakes. Presented at 1971 Winter Meet. of Amer. Soc. Agric. Eng., Chicago, Ill.
1973. Rates of photosynthesis and phytoplankton growth in Shagawa Lake, Minnesota. Environ. Prot. Agency, Ecol. Res. Ser., EPA-R3-73-039. Washington, D.C. 70 p.

MENDAY, D. and A. BUCK
1972. A shockwave technique to collapse the vacuoles of blue-green algae. Water Res. 6:279-284.

MENN, C.T.
1965. Appraisal of water hyacinth control with 2,4-D sprayed from helicopters. Prog. Fish-Cult. 27(4):228-229.

MERCIER, P.
1955. Aeration partielle sous-lacustrine d'un lac eutrope [In French]. Verh. Int. Ver. Limnol. 10:294-297.

MERCIER, P. and S. GAY
1954. Effets de l'aeration artificielle sous-lacustre au lac de Bret. [In French]. Schweizer z.f. Hydrol. 16:248-308.

MERCIER, P. and J. PERRET
1949. Aeration station of Lake Bret. Monatsbull. Schweiz. Ver. Gas. u. Wasserfachm 29:25.

MERNA, J.W.
1965. Aeration of winterkill lakes. Prog. Fish-Cult. 27(4):199-202.

METCALF AND EDDY ENGINEERS
1970. A comprehensive pollution abatement program for the Occoquan watershed. Boston, Mass.

MILLER, R.R.
1952. A review of the *Triaenophorus* problem in Canadian lakes. Fish. Res. Bd. Can., Bull. No. 95. Ottawa, Ont. 42 p.

MINDER, V.L.
1948. Der Rotsee–Eine limnologische Skizze und geplante Versuche zur Behebung von Missstanden [In German]. Schweizerische Zeitschrift für Hydrologie 11:245-253.

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD, ENGLAND AND WALES
1968. The control of aquatic weed by grass carp. Minist. Agric. Fish Fd. Salmon and Freshwater Fish. Res. Prog. Rep. 13-14.

MITRA, E.
1970. Use of copper sulfate in pond soils for the control of rooted aquatic weeds. Sci. and Cult. 36(3):159-161.

MOELLMER, W.O. and M.T. UNG
1972. A practical example of the use of simulation to develop an optimal plan for water quality control. Simulation 19(4).

MOFFA, P.E., F.J. DREHWING, J.M. KARANIK, and J.J. HENNIGAN
1971. Comprehensive program for an eutrophic lake. Presented at the 14th Conf. of Great Lakes Res.

MOON, C.E.
1972. The effect of wastewater diversion on the nutrient budget of Lake Sammamish. M.S. Thesis, Univ. of Wash.

MORETTI, G., L. ZINNAI, and C. ANTONELLI
1962. Experimental evidence of chemical weed eradication in Lake Trasimeno [In Italian]. Rivista Di Idrobiologia 1 (2-3):95-114.

MORI, S.
1972. Fourth report of the regular limnological survey of Lake Biwa, 1971. Mem. Fac. Sci. Kyoto Univ. Ser. Biol. 6:59-90.

MORRIS, D.J.
1971. Selective treatment and restocking of Ascarate Park lakes. Texas Parks and Wildl. Dep., Job Completion Rep., Proj. No. F-14-d-12. 10 p.

MORTIMER, C.H.
1941. The exchange of dissolved substances between mud and water in lakes. Ecology 29:280-329.

MOSSIER, J.N.
1968. Methods of harvesting or control of aquatic plants. Tech. Rep. OWRR A-0030-Wis. Univ. of Wis. Water Resour. Cent., Madison, Wis.

MOYLE, J.B. and W.D. CLOTHIER
1959. Effects of management and winter oxygen levels on the fish population of a prairie lake. Trans. Amer. Fish. Soc. 88:178-185.

MOYLE, J.B., J.H. KUEHN, and C.R. BURROWS
1950. Fish population and catch data from Minnesota lakes. Trans. Amer. Fish. Soc. 78:163-175.

MULLAN, J.W.
1970. Annual project report, fishery management program. Rocky Mountain Arsenal. U.S. Dep. Inter., Bur. of Sport Fish and Wildl. Vernal, Utah.

MUNRO, J.
1966. A limnological survey of Lake McIlwaine, Rhodesia. Hydrobiologia 28:281-308.

MURPHY, C.B., JR.
1973. Effect of restricted use of phosphate-based detergents on Onondaga Lake. Science 182(4110):379-381.

MURPHY, C.B., JR., P.E. MOFFA, and J.M. KARANIK
1973. Effects of nutrient reductions on Onondaga Lake. Presented at the 46th Ann. Conf. Water Pollut. Control Fed. Cleveland, Ohio. 13 p.

MURRO, R.P. and D.S. YEAPLE
1971. Engineering methodology for river and stream aeration. Environ. Prot. Agency, Water Pollut. Control Res. Ser., Rep. No. 16080FSN. 119 p.

NALEWAJKO, C.
1966. Dry weight, ash, and volume data for some freshwater planktonic algae. Fish. Res. Bd. Can. 23:1285-1288.

NATIONAL ACADEMY OF SCIENCES
1969. Eutrophication: causes, consequences, correctives. Washington, D.C. 661 p.

NATIONAL ASSOCATION OF COUNTIES RESEARCH FOUNDATION
1970. Community action guidebook for soil erosion and sediment control. Fed. Water Qual. Adm., Water Pollut. Control Res. Ser., Rep. 15030 DTL 05/70. 35 p.

NATIONAL INDUSTRIAL POLLUTION CONTROL COUNCIL
1970. Detergents. Washington, D.C. 16 p.

NATURE
1968. Clearance by carp. 220:322-323.

NEEDHAM, R.G.
1966. Effects of toxaphene on plankton and aquatic invertebrates in North Dakota lakes. U.S. Dep. of the Inter., Bur. of Sport Fish. and Wildl. Resour. Publ. 8. Washington, D.C. 16 p.

NEEL, J.K., S.A. PETERSON, and W.L. SMITH
1973. Weed harvest and lake nutrient dynamics. Environ. Prot. Agency, Ecol. Res. Ser., EPA-660/3-73-001. Washington, D.C. 91 p.

NEESS, J.C.
1946. Development and status of pond fertilization in Central Europe. Trans. Amer. Fish Soc. 76:335-358.

NEESS, J.C., W.J. HELM, and C.W. THREINEN
1957. Some vital statistics in a heavily exploited population of carp. J. Wildl. Manage. 21(3):279-292.

NELSON, HALEY, PATTERSON AND QUIRK, INC.
To be published. A regional water quality and sewerage plan for the Three Lakes Water and Sanitary District, Vol. I and II. Greeley, Colo.

NEW HAMPSHIRE WATER SUPPLY AND POLLUTION CONTROL COMMISSION
1971. Algae control by mixing. Concord, N.H. 103 p.

NEW ZEALAND OUTDOOR
1965. Destratification of impounded water. 30(4):16-19.

NICHOLS, S.A.
1971. The distribution and control of macrophyte biomass in Lake Wingra. Tech. Rep. OWRR. B-019-Wis. Univ. of Wis. Water Resour. Cent., Madison, Wis. 132 p.
1972. The aquatic vegetation of the Chippewa Flowage. Appendix T. Chippewa Flowage Invest. Inland Lake Demonstr. Proj., Upper Great Lakes Reg. Comm. Madison, Wis.
1974. Mechanical and habitat manipulation for aquatic plant management/a review of techniques. Department of Natural Resources, Tech. Bull. No. 76. Madison, Wis.

NICHOLS, S.A. and G. COTTAM
1972. Harvesting as a control for aquatic plants. Water Res. Bull. 8(6):1205-1210.

NICKERSON, H.
1961. Gloucester-forced circulation of Babson reservoir. Q. publ. of the Div. of Sanit. Eng., Mass. Dep. of Public Health, pp. 1-10. Boston, Mass.

NIEDERSÄCHSISCHES, LANDESAMT F. BODENFORSCHUNG
1972. Limnogeologische Untersuchungen im Dümmer-Becken im Hinblick auf seine Bedeutung als Natur- und Landschaftsschutzgebiet [In German; English summary]. Hannover, West Germany. 231 p.

NIKOLSKII, C.V., B.V. VESIGIN, A.P. MAKEEVA, and G.V. POPOVA.
1968. Investigating herbivorous fish and their introduction for fish farming and for cleaning reservoirs. Vesk. Mosk. Univ. (Biol. Pochvoved)2:24-31(R).

NORTHCOTE, T.G.
1967. An investigation of summer limnological conditions in Chain Lake, British Columbia, prior to introduction of low nutrient water from Shinish Creek. B.C. Fish and Wildl. Br., Manage. Rep. 55. 19 p.
1970. Advance in management of fish in natural lakes of western North America, pp. 129-139. *In:* A century of fisheries in North America. Amer. Fish. Soc. Spec. Publ. No. 7. Washington, D.C.
1972. Kootenay Lake: man's effects on the salmonid community. Fish. Res. Bd. Can. 29(6):861-865.
In press. a. Some impacts of man on Kootenay Lake and its salmonids. Tech. Rep. Great Lakes Fish. Comm.
In press. b. Some effects of mysid introduction and nutrient enrichment on a large oligotrophic lake and its salmonids. Verh. Internat. Verein. Limnol. 18.

NUNNALLEE, D.A.
1968. Engineering aspects of nuisance algal control in Moses Lake. M.S. Thesis, Civ. Eng. Univ. of Wash. Seattle, Wash. 126 p.

NYE, W.B.
1972. The hazardous material spill experience in Shawnee Lake, Ohio–a case history, pp. 217-219. *In:* Control of hazardous spills. Proc. of the 1972 Natl. Conf. on Control of Hazardous Material Spills.

OBERSTE BAUBEHÖRDE IM BAYERISCHEN STAATSMINISTERIUM DES INNERN.
1971. Seereinheltung in Bayern [In German] Munich, West Germany. 32 p.

O'DONNELL, D.J.
1943. Control of *Hydrodictyon reticulatum* in small ponds. Trans. Amer. Fish. Soc. 73:59-62.

ODUM, E.P.
1971. Fundamentals of ecology. 3rd ed., W.B. Saunders Co., Philadelphia, Penn. 574 p.

OGLESBY, R.T.
1968a. Dilution effects on nutrients and primary productivity. Rep. WPD-38-01-03, Dep. of Civ. Eng., Univ. of Wash. Seattle, Wash. 40 p.
1968b. Effects of controlled nutrient dilution of a eutrophic lake. Water Res. 2:106-108.
1969. Effects of controlled nutrient dilution on the eutrophication of a lake, pp. 482-493. *In:* Eutrophication: causes, consequences, correctives. Natl. Acad. of Sci., Washington, D.C.

OGLESBY, R.T. and D.J. ALLEE, (eds).
1969. Ecology of Cayuga Lake and the proposed bell station (nuclear powered). Publ. No. 27, Cornell Water Res. and Mar. Sci. Cent. Ithaca, N.Y. 466 p.

OGLESBY, R.T. and W.T. EDMONDSON
1966. Control of eutrophication. Water Pollut. Control Fed. 28 (9).

OHLE, W.
1972. Zur Seentherapie. Ein Forschungsprojekt am Grebiner See. Schrift des Max-Planck-Instituts für Limnologie, Symposium Semisaeculare Societas Internationalis Limnologiae, 49-52. Plön, West Germany.

OKUN, D.A.
1971. Environmental impact of phosphates in detergents, pp.

754-756. *In:* Detergents. Part 3. Hearings on S.1478 before the Subcommittee on the Environment, Committee on Commerce, U.S. Senate. 92nd Congr. First Sess. Serial No. 92-50, U.S. Gov. Print. Off., Washington, D.C.

OLSZEWSKI, P.
1961. Versuch einer ableitung des hypolimnischen wassers aus einem See [In German] Verh. Internat. Verein. Limnol. 14:855-861.
1971. Dotychczasowe wyniki eksperymentu nad od[illegible]adzaniem Jeziora Kortowskiego. Zesz. nauk. WSR Olszt., ser. C, suppl. 3, 23-31.

ONONDAGA COUNTY, DEPT. OF PUBLIC WORKS AND O'BRIEN AND GERE ENGINEERS, INC.
1971. Water Qual. Off., Environ. Prot. Agency.

OSKAM, G.
1971. A kinetic model of phytoplankton growth and its use in algal control by reservoir mixing. Presented at the Int. Symp. on Man-Made Lakes. Knoxville, Tenn.

PADAN, E., M. SHILO and N. KISLEV
1967. Isolation of "Cyanophages" from freshwater ponds and their interaction with *Plectonema boryanum.* Virology 32:234-246.

PAGE, T.L.
1971. Algicidal effects of copper sulfate on the structure and productivity of a reservoir plankton community. Ph.D. Thesis, Kent State Univ., Kent. Ohio. 144 p.

PARKER, R.A.
1958. Some effects of thinning on a population of fishes. Ecology 39(2):304-317.

PATRIARCHE, M.H.
1961. Air-induced winter circulation of two shallow Michigan Lakes. J. Wildl. Manage. 25(3):282-289.
1963a. A test of a commercial device to prevent winter oxygen depletion in a Michigan lake. Mich. Inst. for Fish. Res., Rep. No. 1877. Mich. Dep. of Conserv.
1963b. Evaluation of population manipulation on angling success and fish growth in Loon and Dollar lakes, Rifle River area. Inst. for Fish. Res., Rep. No. 1660. Mich. Dep. of Conserv. 23 p.

PATRIARCHE, M.H. and J.W. MERNA
1970. A resume of the winterkill problem. *In:* Scheberger, E. (ed.). A symposium on the management of midwestern winterkill lakes. Amer. Fish. Soc., North Cent. Div., Spec. Pub.

PAYNE, R.R. (coordinator)
1972. The national eutrophication survey. Environ. Prot. Agency, Washington, D.C. 18 p.

PECHLANER, R.
1971. Die Restaurierung des Piburger Sees (Tirol) [In German]. Carinthia II, Sonderheft 31 (Festschrift Findenegg):97-115.

PEELEN, R.
1969. Possibilities to prevent blue-green algal growth in the Delta Region of the Netherlands. Verh. Internat. Verein. Limnol. 17:763-766.

PELTON, J.Z.
1948. Three years of liberalized fishing at Lake Alma, Ohio. Trans. Amer. Fish. Soc. 78:64-69.

PENFOUND, W.T., T.F. HALL, and A.D. HESS
1945. The spring phenology of plants in and around reservoirs in north Alabama with particular reference to malaria control. Ecology 26(4):332-352.

PETERS, L.J.
1961. Experimental control of undesirable fish species in Lake Diversion. Texas Game and Fish Comm., Proj. F-7-R-8. Austin, Texas. 17 p.

PETERSON, J.O., J.P. WALL, T.L. WIRTH, and S.M. BORN
1973. Eutrophication control: nutrient inactivation by chemical precipitation at Horseshoe Lake, Wisconsin. Wis. Dep. of Nat. Resour., Tech. Bull. 62. Madison, Wisconsin. 20 p.

PETERSON, J.O. and D.R. KNAUER
In preparation. Nutrient inactivation as a lake management technique: a summary report. Wis. Dep. Nat. Resour., Tech Bull. Madison, Wis.

PETERSON, S.A., W.L. SMITH, and K.W. MALUEG
1973. Full scale harvest of aquatic plants: how it affects the nutrient budget of an artificially enriched lake. Presented at the 46th Ann. Conf. of the Water Pollut. Control Fed. Cleveland, Ohio.

PHINNEY, H.K. and C.A. PEEK
1961. Klamath Lake, an instance of natural enrichment, pp. 22-27. *In:* Algae and metropolitan wastes. Robt. A. Taft Sanit. Eng. Cent. Tech. Rep. W61-3. Cincinnati, Ohio.

PIERCE, N.D.
1970. Inland lake dredging evaluation. Wis. Dep. Nat. Resour., Tech. Bull. 46. Madison, Wis.

PIERCE, P.C., J.E. FREY, and H.M. YAWN
1963. An evaluation of fishery management techniques utilizing winter drawdowns. Proc. Ann. Conf. Southeast. Assoc. of Game and Fish Comm. 17:347-363. Hot Springs, Arkansas.
1964. Field evaluations of newer aquatic herbicides. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 18:448-474.

PIROZHNIKOV, P.L., A.F. KARPEVICH, A.J. ISAYEO, and Y.I. KARPOVA
1969. Biological principles for improving fisheries in inland waters. Problems of Ichthyol. Amer. Fish. Soc. 9(5):744-751.

PORCELLA, D.B., K.L. SCHMALZ, and W.A. LUCE
1971. Sediment-water nutrient interchange in eutrophic lakes. Proc. Semin. on Eutroph. and Biostim. Univ. Calif., Berkeley, Calif.

POWELL, M.D., W.C. WINTER, and W.R. BODWITCH
1970. Urban soil erosion and sediment control. Environ. Prot. Agency, Water Pollut. Control Res. Ser., 15030 DTL 05/70. 63 p.

POWERS, C.F., et al.
1972. Algal responses to nutrient additions in natural waters. II. Field experiments. Nutrients and Eutrophication, Spec. Symp., 1: 141-154. Amer. Soc. of Limnol. and Oceanogr., Inc.

PRIEGEL, G.R.
1971. Evaluation of intensive freshwater drum removal in Lake Winnebago, Wisconsin, 1955-1966. Wis. Dep. of Nat. Resour., Tech. Bull. No. 47. Madison, Wis. 29 p.

PRIMISING, M. and V. HACKER
1964a. Partial chemical treatment of Porters Lake, Waushara County during 1962, and its affect on the fish population. Wis. Conserv. Dep., Intra-dep. memo. Oshkosh, Wis. 13 p.
1964b. Partial chemical treatment project on Bugh's Lake, Waushara County, 1962, and its affect on fish population. Wis. Conserv. Dep., Intra-dep. memo. Oshkosh, Wis. 9 p.

PROBER, R., Y.Y. HAIMES, M. TERAGUCHI, and W.H. MOSS
Undated. An ecosystem model of lake algae blooms. Case Western Reserve Univ., Cleveland, Ohio. 12 p.

PROPHET, C.W.
1965. Some limnological features of Lyon County State Lake during reflooding. Trans. Kans. Acad. Sci. 67:676-685.
1970. Limnological features of Lyon County Lake after drainage and reflooding. Southwest. Nat. 14:317-325.

PROPHET, C.W., N. YOUNGSTEADT, L. SCHNITTKER
1967. Limnology of Lyon County State Lake during reflooding, April 1964–March 1966. Trans. Kans. Acad. Sci. 69:214-225.

PROTO, D. and R.A. SWEENEY
1973. Annotated bibliography of Lake Ontario limnological and related studies. Vol. 1–Chemistry. Environ. Prot. Agency, Ecol. Res. Ser., EPA-R3-73-028a. Washington, D.C. 102 p.

PROWSE, G.A.
1969. The role of cultured pond fish in the control of eutrophication in lakes and dams. Verh. Internat. Verein. Limnol. 17:714-718.

R.W. BOOKER and ASSOCIATES, INC.
1971. Creve Coeur Lake rehabilitation study. Prepared for the St. Louis Dep. of Parks and Recreation, St. Louis, Mo.

RADKE, M.G., L.S. RITCHIE, and F.F. FERGUSON
1961. Demonstrated control of *Australorlois glabratus* by *Marisa cornvarietis* under field conditions in Puerto Rico. Amer. J. of Trop. Med. and Hyg. 10:370-373.

RAINEY, R.H.
1967. Natural displacement of pollution from the Great Lakes. Science 155:1242-1243.

RAPOZA, D.
1971. Reservoir aeration improves water quality. Public Works, May issue.

RASMUSSEN, D.H.
1960. Preventing a winterkill by use of a compressed-air system. Prog. Fish-Cult. 22 (4):185-187.

RECHT, H.L. and M. GHASSEMI
1970. Kinetics and mechanism of precipitation and nature of the precipitate obtained in phosphate removal from wastewater. Using AL (III) and Fe (III) salts. Fed. Water Qual. Adm., Water Pollut. Control Res. Ser., Rep. 17010 EKI 04/70. 77 pp.

REILICH, H.G.
1972. Technical evaluation of phosphate-free home laundry detergents. Environ. Prot. Agency, Water Pollut. Control Res. Ser., 16080 DVF 02/72. Washington, D.C. 120 p.

REUTER vs. DEPARTMENT OF NATURAL RESOURCES
1969. Administrative finding of effects upon water pollution as prerequisite to issuance of dredging permits. 168 NW 2d 860-863 (Wisconsin 1969).

RICHARDS, M.
1962. Experimental non-game fish eradication program. Idaho Wildl. Rev. 15(1):3-6.

RICKER, W.E. and J. GOTTSCHALK
1940. An experiment in removing coarse fish from a lake. Trans. Amer. Fish. Soc. 70:382-390.

RIDDICK, T.M.
1957. Forced circulation of reservoir waters yields multiple benefits at Ossining, N.Y. Water and Sewage Works 104(6):231-237.

RIDLEY, J.E.
1970. The biology and management of eutrophic reservoirs. Water Treat. Exam. 19:374-399.
1971. Water supply lakes and raw water storage reservoirs. Environ. Prot. Agency, Water Qual. Off.
1972. New approaches to water quality control in impoundments. *In:* Mitchell, R. (ed.). Water pollut. microbiol. New York, N.Y.

RIDLEY, J.E., P. COOLEY, and J.A.P. STEEL
1966. Control of thermal stratification in Thames Valley reservoirs. Proc. Soc. Water Treatment and Exam., 15:225-244.

ROBEL, R.J.
1962. Changes in submersed vegetation following a change in water level. J. Wildl. Manage. 26:221-224.

ROBERTS, W.J.
1969. Dredging to extend reservoir life. Public Works 100(11):98-99.

ROBINSON, E.L., W.H. IRWIN, and J.M. SYMONS
1969. Influence of artificial destratification on plankton populations in impoundments. *In:* Symons, J.M. (ed.). Water quality behavior in reservoirs. Public Health Serv. Pub. No. 1930. Cincinnati, Ohio.

ROCHON, G.
1971. Etude écologique du lac Saint-Joseph, Cté Portneuf. CENTREAU, Pavillon Pouliot, Université Laval. Québec, Canada.

RODENHEFFER, J.A.
1939. The use of brush shelters by fish in Douglas Lake. Mich. Acad. of Sci., Arts and Lett. 25:357-366.

ROGERS, W.A.
1969. A summary of fish disease cases received over a five-year period at the Southeastern Cooperative Fish Disease Laboratory. Proc. Ann. Conf. of Southeast. Assoc. of Game and Fish Comm. 23:353-358.

ROHLICH, G.A.
1963. Origin and quantities of plant nutrients in Lake Mendota, pp. 75-79. *In:* Frey, D.G. (ed.). Limnology in North America. Univ. of Wis. Press, Madison, Wis.

ROHLICH, G.A. and P.D. UTTORMARK
1972. Wastewater treatment and eutrophication. Nutrients and Eutrophication, Special Symposia, 1:231-243. Amer. Soc. of Limnol. and Oceanogr. Inc.

ROSE, E.T.
1954. Blue-green algae control of Storm Lake. Proc. Iowa Acad. Sci. 61:604-614.

ROSE, E.T. and T. MOEN
1952. The increase in game-fish populations in East Okoboji Lake, Iowa, following intensive removal of rough fish. Trans. Amer. Fish. Soc. 82:104-114.

ROSSOLIMO, L.L. and G.S. SHIL'KROT
1971. Effects of forced aeration on a hypereutrophic lake [In Russian]. Akademiya Nauk SSSR Izvestiya, Seriya Geograficheskaya, No. 4, pp. 48-58.

RUKEYSER, W.S.
1972. Fact and foam in the row over phosphates. Reprinted from Fortune, January issue. 8 p.

RUSSELL and AXON, INC.
1968. Report on correction of silting problem at Big Lake. Consultant's Report. Prepared for the Mo. State Park Bd., Proj. No. 6709-13D.

RUTLEDGE, W.P. and J.C. BARRON
1972. The effects of the removal of stunted white crappie on the remaining crappie population of Meridian State Park Lake, Bosque, Texas. Texas Parks and Wildl. Dep. Tech. Ser. No. 12. 41 p.

RYCKMAN, EDGERLEY, TOMLINSON and ASSOCIATES, INC.
1971. Pesticide poisoning of Pond Lick Lake, Ohio. Investigation and resolution. Environ. Prot. Agency, Water Pollut. Control, Oil and Hazardous Materials Program Ser., OHM 71 06 002. Washington, D.C. 156 p.

RYDEN, J.C., J.K. SYERS, and R.F. HARRIS
1972. Nutrient enrichment of runoff waters by soils. Phase I: phosphorus enrichment potential of urban soils in the City of Madison. Tech. Rep. OWRR A-038-Wis. Univ. of Wis. Water Resour. Cent., Madison, Wis. 70 p.

RYDER, R.A.
1970. Major advances in fisheries management in North American glacial lakes, pp. 115-127. *In:* A century of fisheries in North America. Amer. Fish. Soc. Spec. Publ. No. 7. Washington, D.C.

SABANAS, M., S.A. GAONKAR, and W.J. OSWALD
1970. Removal of algae in natural bodies of water. The environmental challenge of the 70's. Inst. of Environ. Sci., Boston, Mass.

SAFFERMAN, R.S. and M.E. MORRIS
1963. Algal virus: isolation. Science 140:679-680.

SAFFERMAN, R.S., I.R. SCHNEIDER, R.L. STEELE, M.E. MORRIS, and T.O. DIENER
1969. Phycovirus SM-1: virus infecting unicellular blue-green algae. Virology 37:386-395.

SANDERS, D.R.S.
1971. Preliminary report of aquatic plant control on Black Lake, Louisiana. Abstract, Proc. South. Weed Sci. Soc. Conf. 25:392.

SANDOZ, O.
1956. Changes in the fish population of Lake Murray following the reduction of gizzard shad numbers. Proc. Okla. Acad. Sci. 37:174-181.

SAVARD, P. and D. BODINE
1971. The algal flora of Conesus Lake. Proc. Roch. Acad. Sci. 12:146-159.

SAWYER, C.N.
1947. Fertilization of lakes by agricultural and urban drainage. J. New. Engl. Waste Works Assoc. 51:109-127.

SAWYER, C. N., J. B. LACKEY, and A. T. LENZ
1943. Investigation of the odor nuisances in the Madison lakes, particularly lakes Monona, Waubesa and Kegonsa, from July 1942 to July 1943. Rep. to the Governor's Comm., Madison, Wis. 79 p.
1945. Investigation of the odor nuisances in the Madison lakes, particularly lakes Monona, Waubesa, and Kegonsa, from July 1943 to July 1944. Rep. to the Governor's Comm. Madison, Wis. 92 p.

SAWYER, P. J.
1970. The effects of copper sulfate on certain algae and zooplankters in Winnisquam Lake, New Hampshire. Completion Rep., Proj. No. A-004-NH, Water Resour. Res. Cent., Univ. of N. H. 24 p.

SAWYER, P. J., J. J. GENTILE, and J. SASNER, JR.
1968. Demonstration of a toxin from *Aphanizomenon flos-aquae* (L.) Ralfs. Can. J. Microbiol. 14:1199.

SCHMITZ, W. R. and R. E. HETFELD
1965. Predation by introduced muskellunge on perch and bass, II: years 8-9. Wis. Acad. Sci., Arts and Lett. 54:273-282.

SCHNEIDER, R. F. and J. A. LITTLE
1971. The rise and fall of Lake Apopka - a case history of reservoir management. Presented at the Symp. on Man-made Lakes. Knoxville, Tenn.

SCHRÖDER, R.
1973. Release of plant nutrients from reed border and its transport

into the open waters of the Bodensee-Untersee. Arch. Hydrobiol. 71:145-158.

SCHRYER, F., J. ROY, and W. COLE
1969. Progress Report, Project F-15-R-4, Job No. D-1-4, Kans. For., Fish and Game Comm. 7 p.

SCHULTS, D. W. and K. W. MALUEG
1973. Uptake of radiophosphorus by rooted aquatic plants. Environ. Prot. Agency, Northwest Lab. Corvallis, Oreg. 25 p.

SCIDMORE, W. J.
1960. Evaluation of removal as a means of improving growth rates and average size of stunted fish. Minn. Dep. Conserv. Invest., 2:42-51.

SCIDMORE, W. J. and D. E. WOODS
1961. Changes in the fish populations of four southern Minnesota lakes subjected to rough fish removal. Minn. Dep. Conserv. Fish and Game Invest., Fish. Ser. 3:1-19.

SCOTT, M.
1971. The estimated nutrient budget of Annabessacook Lake. Presented at the Workshop and Conference on Reclamation of Maine's Dying Lakes. Univ. of Maine, Bangor, Maine.

SCOTT, W. and A. L. FOLEY
1919. A method of direct aeration of stored waters. Proc. Ind. Acad. Sci., pp. 71-73.

SEABURG, K. G.
1966. Aerator evaluation. Mont. Fish and Game Dep., Job Completion Rep., Proj. F-12-R-11, Job III. 12 p.

SEASTEDT, T. R. and J. F. TIBBS
1972. Water quality and related land use in the Flathead drainage. Rep. to the Environ. Prot. Agency, Denver, Colo.

SEATTLE UNIVERSITY
1970. The oxygen uptake demand of resuspended bottom sediments. Environ. Prot. Agency, Water Pollut. Control Res. Ser., 16070 DCD 09/70.

SEIDEL, K.
1966. Reinigung von Gewässern durch hohere Pflauzen [In German]. Die Naturwissenschalten 53:289-297.

SELBIG, W.
1970. Chemical rehabilitation of chronic winterkill lakes. *In:* Schneberger, E. (ed.). A symposium on the management of midwestern winterkill lakes. Amer. Fish. Soc., North Central Div., Spec. Pub.

SENAT VON BERLIN
1971. Massnahmen zur Reinhaltung der Berliner Seen. Rep. 1971.

SEPPÄNEN, P.
1964. Harinjarvi, sairaan jaroen paraneminen [In Finnish, English summary]. Pres. at the Limnologisymposion 1964. Suomen Limnologinen Yhdistys, Limnologiska Foreningen i Finland.
1967. Eutrofoituvien jarviemme mangaanipitoisuuden merkityksesta vesihuollolle [In Finnish, English summary]. Pres. at the Limnologisymposion 1967. Suomen Limnologinen Yhdistys, Limnologiska Foreningen i Finland.
1973. Limnological principles and possibilities within lake restoration [In Finnish, English summary]. Vesihallituksen julkaisuja (Publ. of the Nat. Bd. of Waters), No. 3, 174 p.

SHANNON, E. E. and P. L. BREZONIK
1972. Relationships between lake trophic state and nitrogen and phosphorus loading rates. Environ. Sci. and Technol. 6(8):719-725.

SHANNON, E. E. and D. T. VACHON
1973. The Welland Canal water quality control experiments (phase I). Environ. Prot. Serv., Technol. Dev. Rep. No. EPS 4-WP-73-1, Ottawa, Ont., Canada, 43 p.

SHEFFIELD, C. W. and W. M. BISHOP
1973. Effects of nutrients on lake restoration projects. Presented at the 46th Ann. Conf. Water Pollut. Control Fed. Cleveland, Ohio, 58 p.

SHEFFIELD, C. W. and W. H. KUHRT
1970. Lake Apopka–its decline and proposed restoration. Proc. Fla. Environ. Eng. Conf. on Water Pollut. Control. Fla. Univ. Eng. and Ind. Exp. Sta. Bull., Ser. 135, 24:130-146.

SHEPHERD, T. A.
1968. Dilution effects on algal standing crop in a eutrophic lake. M.S. Thesis, Civ. Eng., Univ. of Wash., Seattle, Wash. 124 p.

SHIELDS, J. T.
1958. Experimental control of carp reproduction through water drawdowns in Fort Randall Reservoir, S. D. Trans. Amer. Fish. Soc. 87:23-33.

SHULER, J.
1972. How a lake aeration system overcame water consumer complaints. Public Works, May:92-93.

SILLIMAN, R. P. and J. S. GUTSELL
1958. Experimental exploitation of fish populations. U.S. Fish and Wildl. Serv., Fish. Bull. 58, pp. 215-252.

SILLS, J. B.
1964. A report on the use of karmex to control filamentous algae in fish ponds. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 18:474-479.

SILVEY, J. K. G., K. W. STEWART, and W. D. PEARSON
1971. Ecol. study of White Rock Lake. Inst. for Environ. Stud., N. Texas State Univ. Denton, Texas. 46 p. (mimeo).

SIMMS, D. H.
1970. The Soil Conservation Service. Praeger Pub., New York, N. Y. 239 p.

SINGH, R. N. and P. K. SINGH
1967. Isolation of cyanophages from India. Nature 216:1020-1021.

SKETELJ, J. and M. REJIC
1966. Pollutional phases of Lake Bled, pp. 345-368. *In:* Advances in water pollution research. Proc. 2nd. Int. Conf. Water Pollut. Res., Vol. I, Pergamon Press, Oxford, United Kingdom.

SMITH, G. E. and B. G. ISOM
1967. Investigations of effects of largescale applications of 2,4-D on aquatic fauna and water quality. Presticides Monitoring J. 1(3):16-31.

SMITH, G. E., T. F. HALL, and R. A. STANLEY
1967. Eurasian watermilfoil in the Tennessee Valley. Weeds 15:95-98.

SMITH, S. A.
Undated. Results of lake rehabilitation at Snake Lake. In-house Rep. Wis. Dep. of Nat. Resour. Madison, Wis. 4 p.

SMITH, S. A., J. O. PETERSON, S. A. NICHOLS, and S. M. BORN
1972. Lake deepening by sediment consolidation–Jyme Lake. Inland Lake Demonstr. Proj. Upper Great Lakes Reg. Comm. Madison, Wis. 36 p.

SMITH, W. A., JR.
1959. Shad management in reservoirs. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 12:143-147.

SMITHERMAN, R. D.
Undated. Predicting and preventing fish kills. Proj. F-010-R-10. Job No. 7. Ala. Dep. of Conserv.

SNIESKO, S. F.
1941. Pond fishing farming in Poland, pp. 227-240. *In:* A symp. on hydrobiol. Univ. of Wis. Press, Madison, Wis.

SNOW, H. E.
1960. Bluegill at Murphy Flowage. Wis. Conserv. Bull 25(3):4,12-14.
1962. A comparison of the fish population in Murphy Flowage, Wisconsin, before and after a panfish removal program. Wis. Conserv. Dep., Madison, Wis. 5 p. (mimeo).
1968. Stocking of muskellunge and walleye as a panfish control practice in Clear Lake, Sawyer County. Res. Rep. 38. Dep. of Nat. Resour., Madison, Wis. 18 p.
1971. Harvest and feeding habits of largemouth bass in Murphy Flowage, Wisconsin. Dep. of Nat. Resour., Tech. Bull. No. 50. Madison, Wis. 25 p.

SOIL CONSERVATION SOCIETY OF AMERICA
1971. A primer on agricultural pollution. J. Soil and Water Conserv. 26(2):44-65.

SONZOGNI, W.C. and G.F. LEE
1972. Effect of diversion of domestic waste waters on phosphorus content and eutrophication of the Madison lakes. Presented at the 73rd Nat. Meet., Amer. Inst. of Chem. Eng., Minneapolis, Minn. 30 p.
Undated. Nutrient sources for Lake Mendota–1972. Rep. of the Univ. of Wis. Water Chem. Program. Madison, Wis.

SPEECE, R. E.
1969. The use of pure oxygen in river and impoundment aeration. Presented at the 24th Ind. Waste Conf. Purdue, Indiana.
1971. Hypolimnion aeration. Amer. Water Works Assoc. 64(1):6-9.

SPITLER, R. J.
1970. An analysis of rotenone treatments for elimination of fish populations in southern Michigan lakes, 1957-1967. Mich. Acad. 3(1):77-82.

SREENIVASAN, A.
1969. Eutrophication trends in a chain of artificial lakes in Madras (India). Environ. Health 11:392-401.

STATE OF MINNESOTA
1971. Classification scheme for public waters. Minn. Dep. Nat. Resour., Shoreland Manage. Supp. Rep. No. 1. 22 p.

STEEL, E. W. and B. B. EWING
1954. Controlling watermilfoil in a Texas reservoir. Public Works 85(10):89-90.

STEENIS, J. H., L. P. SMITH, and H. P. COFER
1958. Studies on cattail management in the Northeast. Trans. Northeast. Wildl. Congr., pp. 149-155.

STEWART, J. R. and R. M. BROWN
1969. Cytophaga that kills or lyses algae. Science 164:1523-1524.

STEWART, K. and G. A. ROHLICH
1967. Eutrophication–a review. State Water Qual. Control Bd. Publ. No. 34, State of Calif. 188 p.

STOCK, J. N. and O. B. COPE
1969. Some effect of TEPA, an insect chemosterilant on the guppy, *Poecilia reticulata*. Trans. Amer. Fish. Soc. 98(2):280-287.

STOLTENBERG, D. H.
1972. How to reclaim a poisoned lake. Public Works 103(3):59-61.

STOTT, B. and T. O. ROBSON
1970. Efficiency of grass carp (*Ctenopharyngodon idella* Val.) in controlling submerged water weeds. Nature 226:870.

STOTT, B., D. G. CROSS, R. E. ISZARD, and T. O. ROBSON
1971. Recent work on grass carp in the United Kingdom from the standpoint of its economics in controlling submerged aquatic plants. Proc. Eur. Weed Res. Counc., 3rd Int. Symp. Aquatic Weeds, pp. 105-116. Oxford.

STRINGER, G. E. and R. G. McMYNN
1960. Three years' use of toxaphene as a fish toxicant in British Columbia. Can. Fish Cult. 28:37-44.

STROUD, R. H.
1969. Some factors affecting reservoir fisheries. SFI Bulletin No. 210, pp. 1-4. Sport Fish. Inst., Washington, D.C.

STROUD, R. H. and R. G. MARTIN
1968. Fish conservation highlights 1963-1967. Sport Fish. Inst., Washington, D.C. 147 p.

STUMM, W. and J. O. LECKIE
1970. Phosphate exchange with sediments: its role in the productivity of surface waters. Presented at the 5th Int. Water Pollut. Res. Conf., San Francisco, Calif.

SUKOPP, H.
1971. Effects of man, especially recreational activities on littoral macrophytes. Hydrobiologia 12:331-340.
1973. Conservation of wetlands in Central Europe. Pol. Arch. Hydrobiol. 20:227-232.

SUKOPP, H. and W. KUNICK
1969. Die Ufervegetation der Berliner Havel [In German]. Natur und Landschaft 44:287-292.

SURBER, E. W.
1943. Weed control in hard water ponds with copper sulfate and sodium arsenite. Trans. North Amer. Wildl. Conf. 8:132-141.

SWANBERG, P. O.
1972. Hornborgasjön som fågelsjö. Ornitologisk undersökning i Statens naturvårdsverks utredning om sjöns framtid. -Statens naturvårdsverk. Stockholm. (mimeo).

SWERDON, P. M. and R. R. KOUNTZ
1973. Sediment runoff control at highway construction sites. Penn. State Univ. Eng., Res. Bull. B-108. 70 p.

SWINGLE, H. S., E. E. PRATHER, and J. M. LAWRENCE
1953. Partial poisoning of overcrowded fish populations. Ala. Polytech. Inst., Agric. Exp. Sta. Circ. 113, 15 p.

SYERS, J. K., R.F. HARRIS and D.E. ARMSTRONG
1973. Phosphate chemistry in lake sediments. J. Environ. Qual. 2(1):1-14.

SYLVESTER, R. O. and G. C. ANDERSON
1960. An engineering and ecological study for the rehabilitation of Green Lake. Univ. of Wash., Seattle, Wash. 235 p.
1964. A lake's response to its environment. Amer. Soc. of Civ. Eng., Sani. Eng. Div. 90 (SA1):1-22.

SYLVESTER, R. O. and R. T. OGLESBY
1964. The Moses Lake environment. Univ. of Wash., Dep. Civ. Eng., Seattle Wash., 89 p.

SYLVESTER, R. O. and R. W. SEABLOOM
1965. Quality of impounded water as influenced by site preparation. Amer. Water Works Assoc. 57(2):1528-1546.

SYMONS, J.M., W.H. IRWIN, R.M. CLARK and G.G. ROBECK
1966. Management and measurement of "DO" in impoundments. Proc. ASCE Natl. Symp. on Qual. Stand. for Nat. Waters. Ann Arbor, Mich.

SYMONS, J.M., W.H. IRWIN and G.G. ROBECK
1967a. Reservoir water quality control by destratification. Fed. Water Pollut. Control Adm., Cincinnati, Ohio.

SYMONS, J. M., W. H. IRWIN, E. L. ROBINSON and G. G. ROBECK
1967b. Impoundment destratification for raw water quality control using either mechanical- or diffused-air pumping. Amer. Water Works Assoc. 59(10):1268-1291.

SYMONS, J. M., J. K. CARSWELL, and G. G. ROBECK
1970. Mixing of water supply reservoirs for quality control. Amer. Water Works Assoc. 62(5):322-334.

SZE, P. and J. M. KINGSBURY
1972. Distribution of phytoplankton in a polluted saline lake, Onondaga Lake, New York. J. Phycol. 8:25-37.

TANNER, H. A. and M. L. HAYES
1955. Evaluation of toxaphene as a fish poison. Colo. Coop. Fish. Res. Unit, Q. Rep., L No. 3-4:31-39.

TARZWELL, C. M.
1940. The fish population of a small pond in northern Alabama. Trans. North Amer. Wildl. Conf. 5:245-251.

TAYLOR, G. D.
1971. Evaluation of partial diversion of Shinish Creek into Chain Lake (1970). B. C. Fish and Wildl. Br., M.S. 21 p.
1972. Evaluation of partial diversion of Shinish Creek into Chain Lake (1971). B. C. Fish and Wildl. Br., M.S. 14 p.

TECHNICAL ADVISORY AND INVESTIGATIONS ACTIVITIES, TECHNICAL SERVICES PROGRAM
1966. Fertilization and algae in Lake Sebasticook, Maine. Fed. Water Pollut. Control Adm., Robert A. Taft Sanit. Eng. Cent. Cincinnati, Ohio. 124 p.

TENNEY, M. W.
1972. Fly ash can have potential applications in the restoration of polluted lakes. Reprint. from Aware, April issue.

TENNEY, M. W. and W. F. ECHELBERGER, JR.
1970. Fly ash utilization in the treatment of polluted waters. Reprint. from Bur. of Mines Inf. Circ. 8488, Ash Util. Proc., pp. 237-265.

TENNEY, M. W., W. F. ECHELBERGER, JR., P. C. SINGER F. H. VERHOFF, and W. A. GARVEY
1972. Biogeochemical modelling of eutrophic lakes for water quality improvement. *In:* Advances in water pollution research. Pergamon Press, Oxford and New York.

TENNEY, M. W., S. M. YAKSICH, and J. V. DEPINTO
In preparation. Restoration of water bodies. *In:* B. G. Liptak (ed.). Environ. eng. handb. Chilton Press, Philadelphia, Pennsylvania.

THE DOW CHEMICAL COMPANY
Undated. Lake Needwood : assured an additional 150 years of life. Midland, Mich. 4 p.

THOMAS, E. A.
1953. Empirische und experimentelle Untersuchungen zur Konntnis der Minimumstoffe in 46 Seen der Schweiz. und angrenzender Gebiete [In German]. Schweiz. Ver. Gas & Wasserfachm. 2:1-15.
1965. The eutrophication of lakes and rivers, cause and prevention, pp. 299-305. *In:* Biological problems in water pollution. Third semin., August 13-17, 1962. Public Health Serv. No. 999-WP-25. Washington, D.C.

1966. Der Pfaffikersee vor, wahrend, und nach kunstlicher Durchmisching [In German]. Verh. Internat. Verein. Limnol. 16:144-152.
1971. Oligotrophierung des Zürichsees [In German]. Vierteljahrsschr. Natf. Ges. Zürich 116:165-179.

THOMAS. E. A. and H. RAI
1970. Phosphatelimination in 10 kommunalen Klaranlagen [In German]. Gas, Wasser, Abwasser, 50:179-190.

THOMASTON, W. W.
1962. The results of population alteration and factors affecting balance in farm ponds in Georgia. Proc. Ann. Conf. Southeast. Assoc. Game and Fish Comm. 16:361-370.

THREINEN, C. W.
1949. The effect of carp upon the normal aquatic habitat. Wis. Conserv. Dep., Fish. Biol. Sect., Invest. Rep. No. 709. Madison, Wis. 21 p.
1952. History, harvest and management of the Lake Koshkonong fishery. Wis. Conserv. Dep., Fish. Biol. Invest. Rep. No. 668. Madison, Wis. 33 p.
1960. Results of walleye fingerling stocking in lakes with stunted panfish. Summary Rep., Wis. Conserv. Dep. Madison, Wis. 4 p.

TOERIEN, D. F. and D. J. STEYN
1973. The application of algal bioassays in eutrophication analyses. Presented at the llth Conf. of the South Afr. Soc. for Plant Pathol. and Microbiol. Salisbury, Rhodesia.

TOETZ, D., J. WILHM, and R. SUMMERFELT
1972. Biological effects of artificial destratification and aeration in lakes and reservoirs–analysis and bibliography. U.S. Dep. Inter., Bur. of Reclam. Rep. No. 12-D-2121 and -2122 (REC-ERC-72-33). Denver, Colo. 117 p.

TOMPKINS, W. A. and C. BRIDGES
1958. The use of copper sulfate to increase fyke-net catches. Prog. Fish-Cult. 20(1):16-20.

TOMPKINS, W. A. and J. W. MULLAN
1958. Selective poisoning as a management tool in stratified trout ponds in Massachusetts. Prog. Fish-Cult. 20(3):117-123.

TUBB, R.
1966. Limnological conditions in aerated lakes of the Turtle Mountains. N. D. Game and Fish Dep., Proj. F-2-R-13, Job 19, Rep. A-1001.

TURNER, H. J., R. E. TOWNE, and T. P. FROST
1972. Control of algae by mixing. J. N. Engl. Water Works Assoc. 86(3):267-275.

TURNER, W. R.
1959. Effectiveness of various rotenone-containing preparations in eradicating farm pond fish populations. Fish. Bull. No. 25, Ky. Dep. of Fish and Wildl. Resour. Frankfort, Ky. 22 p.

UHLMANN, D., J. BENNDORF, and W. ALBERT
1971. Prognose des Stoffhaushaltes von Staugewassern nait Hilfe kontinuierlicher oder semikontinuierlicher biologischer Modelle, I: Grundlagen. Int. Revue des Hydrobiol. 56:513-539.

ULRIKSON, G.
1969. Use and effects of cobalt 60 for sterilization of bluegills, *Lepomis macrochirus.* Thesis. Univ. of Mich. Ann Arbor, Mich.

U.S. ARMY COASTAL ENGINEERING RESEARCH CENTER
1966. Shore protection, planning and design. Tech. Rep. No. 4 (3rd ed.). U.S. Gov. Print. Off., Washington, D.C. 401 p.

U. S. ARMY CORPS OF ENGINEERS, NORFOLK DISTRICT and VIRGINIA COMMISSION OF GAME AND INLAND FISHERIES
1972. Final environ. impact statement: Walker Dam Impoundment aquatic plant control proj. Norfolk, Va.

U.S. ARMY CORPS OF ENGINEERS, NORTH-CENTRAL DIVISION
1971. Great Lakes region inventory report, national shoreline study. Chicago, Ill. 219 p. (v. 2, shore protection guidelines, 58 p. and v. 3, shore management guidelines, 56 p.).

U.S. ARMY CORPS OF ENGINEERS, LITTLE ROCK DISTRICT
1972. Table Rock aeration tests. Little Rock, Arkansas.

U.S. DEPARTMENT OF AGRICULTURE
1963. Proc. Federal Interagency sedimentation conf., Agric. Res. Serv. Misc. Publ. No. 970. 933 p.
1969. Standards and specifications for soil erosion and sediment control in urbanizing areas. Soil Conserv. Serv.
1970a. Controlling erosion on construction sites. Soil Conserv. Serv., Agric. Inf. Bull. 347. 31 p.
1970b. Model for developing soil erosion and sediment control ordinance and regulations. Soil Conserv. Serv. (Michigan).
1971. Managing our environment: a report on ways agricultural research fights pollution. Agric. Inf. Bull. No. 351. 50 p.

U.S. ENVIRONMENTAL PROTECTION AGENCY
1970. Water quality conditions in Grand Lake, Shadow Mt. Lake, Lake Granby. Pac. Southwest Reg., San Francisco, Calif.
1971a. Control of sediments resulting from highway construction and land development. Off. of Water Programs. 50 p.
1971b. Agricultural pollution of the Great Lakes basin. Water Qual. Off., Rep. No. 13020. 94 p.
1972. Guidelines for erosion and sediment control planning and implementation. Environ. Prot. Technol. Ser., R2-72-O15. Office of Research and Monitoring. 228 p.
1973. Measures for the restoration and enhancement of quality of freshwater lakes. EPA-430/9-73-005. Washington, D.C. 238 p.

VAN DER LINGEN, M. I.
1960. Some observations on the limnology of water storage reservoirs and natural lakes in Central Africa. Proc. First Fed. Sci. Congr., Rhodesia Sci. Assoc., Salisbury, 333-337.

VAN RAY, L. C.
1968. Evaluation of artificial aeration in Stockade Lake. S. D. Dep. of Game, Fish and Parks, Proj. F-15-R-3, Job 1.

VERHOFF, F. H., W. F. ECHELBERGER, JR., M. W. TENNEY, P. C. SINGER, and C. F. CORDEIRO
1971. Lake water quality prediction through systems modeling. Presented at the Computer Simulation Conf. Boston, Mass.

VERNET, J. P., M. MEYBECK, A. PACHOUD and G. SCOLARI
1971. Le Léman: une synthese bibliographique. Bull. Bur. Rech. géol. minière 2e série., sect. IV/2, 47-84.

VIK, R.
1967. Makemark–Kontroll [In Norwegian, English summary]. Fauna (Oslo) 20(2):88-95.

VOLLENWEIDER, R. A.
1968. Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication. Organ. for Econ. Co-operation and Dev., Dir. for Sci. Aff. (Reference DAS/CSI/68.27/Bibliography). Paris, France.
1969. Possibilities and limits of elementary models concerning the budget of substances in lakes. Archiv f. Hydrobiologie (66)1:36. Engl. transl. from Dep. of Secr. of State, Transl. Bur., Ottawa, Can. (No. 0343).

von GELDERN, C.E., JR.
1966. Warmwater lake management, pp. 304-312. *In:* Inland fish. manage. Calif. Dep. of Fish and Game, Sacramento, Calif.

WALES, J. H.
1942. Carp control work in Lake Almanor, 1941. Calif. Fish and Game 28:28-33.

WALKER, C. A.
1963. Endothal derivatives as aquatic herbicides in fishery habitats. Weeds 11(3):226-232.
1964a. Simazine and other s-triazine compounds as aquatic herbicides in fish habitats. Weeds 12(2):134-139.
1964b. Dichlobenil as a herbicide in fish habitats. Weeds 12(4):267-269.
1965. Diuron, fenuron, monuron, neburon, and TCA mixtures as aquatic herbicides in fish habitats. Weeds 13(4):297-301.

WALKER, C. R. and J. P. FRY
[?] Physio-chemical characteristics of a new reservoir and effects of hypolimnion discharge on downstream impoundments. Unpubl. rep. Mo. Dep. Conserv.

WALSBY, A. E. and B. BUCKLAND
1969. The isolation and purification of intact gas vesicles from a blue-green alga. Nature (Lond.) 224:716-717.

WALSH, G. E., C. W. MILLER, and P. T. HEITMULLER
1971. Uptake and effects of dichlobenil in a small pond. Bull. Environ. Contam. and Toxicol. 6(3):279-288.

WARNICK, D. C.
1966. Growth rates of yellow perch in two North Dakota lakes after population reduction with toxaphene. U.S. Dep. of the Inter., Bur. of Sport Fish. and Wildl., Resour. Publ. 9. Washington, D.C. 9 p.

WATER AND WASTE TREATMENT JOURNAL
1960. New life for polluted Swedish lakes. 8:65.

WATER AND WATER ENGINEERING
1962. Destratification of impounded water. 66 (March):112-115.

WATER SPECTRUM
1972. Air compressors inject life giving oxygen. Spring:47-48.

WAY, J. M., J. F. NEWMAN, N. W. MOORE, and F. W. KNOGGS
1971. Some ecological effects on the use of paraquat for the control of weeds in small lakes. J. Applied Ecol. 8(2):509-532.

WEEDS TODAY
1972. Steady advances in aquatic weed control. 3(3):6-7.

WEGENER, W. and D. HOLCOMB
1972. Lake Tohopekaliga drawdown. 1971-1972 Annual Progress Report. Fla. Game and Freshwater Fish Comm., Water Level Manipulation Proj. F-29-1.

WELCH, E. B. and D. E. SPYRIDAKIS
1972. Dynamics of nutrient supply and primary production in Lake Sammamish, Washington: Proc. Symp. Res. on Coniferous For. Ecosystems, pp. 301-315. U.S. For. Serv.

WELCH, E. B., R. J. BUCHANAN, R. E. NECE, and R. H. BOGAN
1969. Plankton community and hydraulic characterization preliminary to lake flushing. Dep. of Civ. Eng., Univ. of Wash. Seattle, Wash. 181 p.

WELCH, E. B., J. A. BUCKLEY, and R. M. BUSH
1971. Dilution as a control for nuisance algal blooms. Partial Completion Rep. Dep. of Civ. Eng., Univ. of Wash. Seattle, Wash. 36 p.
1972a. Dilution as an algal bloom control. Water Pollut. Control Fed. 44(12):2245-2265.

WELCH, E. B., R. M. EMERY, C. E. MOON, and D. E. SPYRIDAKIS
1972b. Nutrient income change related to plankton algae. OWRR Proj. Completion Rep., Proj. A-045-Wash. Seattle, Wash. 39 p.

WELDON, L. W. and R. D. BLACKBURN
1967. Water lettuce–nature, problem, and control. Weeds 15(1):5-9.

WELLRICH, T. L. and G. E. SMITH (ed.)
1970. Agricultural practices and water quality. Iowa State Univ. Press. Ames, Iowa. 415 p.

WEST MICHIGAN SHORELINE REGIONAL PLANNING COMMISSION
1971. Muskegon Lake study: a preliminary policy statement. 19 p.

WHALLS, M.
1968. Destratification benefits to fisheries management. Presented at the Seminar on Reservoir Destratification. Calif. Dep. of Water Resour., Los Angeles, Calif.

WHITAKER, E. P.
1967. Simazine in farm ponds. Second Int. Water Symp. Oldenburg, West Germany.

WHITLEY, J. R.
1964. Control of weeds in farm ponds. Proc. North Central Weed Control Conf. 20:31-32.
1965. Control of undesirable vegetation. Prog. Rep., Proj. F-001-R-14, Job No. 3. Mo. Conserv. Dep.

WICKLIFF, E. L.
1948. Fish management and propagation section. pp. 33-57. *In:* Bienn. Rep., Ohio Dep. of Conserv. Columbus, Ohio.

WIESELBERGER, F. and H. HAENDEL
1971. Die Abwasserbeseitigung am Starnberger See [In German]. Zweckverband zur Abwasserbeseitigung am Starnberger See. 38 p.

WIESELBERGER, F. and B. HANISCH
1966. Die Abwasserbeseitigung im Schlierachtal [In German]. Zweckverband zur Abwasserbeseitigung im Schlierachtal. 24 p.

1968. Die Abwasserbeseitigung am Tegernsee [In German[. Zweckverband zur Abwasserbeseitigung am Tegernsee. 28 p.
1969. Die Abwasserbeseitigung am Starnberger See [In German]. Die Wasserwirtschaft 9:248-254.

WILBUR, R. L.
1971. Habitat alteration evaluation, 1970-1971. Ann. Prog. Rep., Fla. Game and Fresh Water Fish Comm., Habitat Manipulation Proj. F-26-2.

WILBUR, R. L. and F. H. LANGFORD
1972a. Habitat alteration evaluation. 1971-1972 Ann. Prog. Rep., Fla. Game and Fresh Water Fish Comm., Habitat Manipulation Proj. F-26-3.
1972b. Habitat alteration evaluation. 1971-1972. Final Rep., Fla. Game and Fresh Water Fish Comm. Habitat Manipulation Proj. F-26.

WILBUR, R. L. and B. E. MAY
1970. Habitat alteration evaluation. 1969-1970 Ann. Prog. Rep., Fla. Game and Fresh Water Fish Comm., Habitat Manipulation Proj. F-26-1.

WILDI, P.
1972. Operating experience and results using the simultaneous precipitation of phosphates in activated sludge plants for 5000 to 30,000 inhabitants in the canton of Zurich. Water Res. 6:477-479. Pergamon Press.

WILDUNG, R. E. and R. L. SCHMIDT
1973. Phosphorus release from lake sediments. Environ. Prot. Agency, Ecol. Res. Ser., EPA-R3-73-024. 185 p.

WILE, I.
1967. Aquatic plant control with diquat, fenac and simazine in Ontario farm ponds. Ont. Water Resour. Comm., Res. Publ. No. 31. 24 p.

WILLÉN, T.
1972. The gradual destruction of Sweden's lakes. Ambio 1(1):6-14.

WILLIAMS, J.D.H., J.K. SYERS, R.F. HARRIS, and D.E. ARMSTRONG
1970. Adsorption and desorption of inorganic phosphorus in a 0.1 M NaCl system. Environ. Sci. and Technol. 4:517-519.

WILLIAMS, R. K.
1970. Practical methods to reduce the intensity and occurrence of algal blooms at Lake McIlwaine. Rhod. Sci. News. 4:54.

WIRTH, T. L.
1970. Mixing and aeration systems in Wisconsin lakes. *In:* Schneberger, E. (ed.). A symposium on the management of midwestern winterkill lakes. Amer. Fish. Soc., North Central Div., Spec. Pub.

WIRTH, T. L. and R. C. DUNST
1967. Limnological changes resulting from artificial destratification and aeration of an impoundment. Wisconsin Conserv. Dep., Fish. Res. Rep. No. 22.

WIRTH, T. L., R. C. DUNST, P. D. UTTORMARK, and W. HILSENHOFF
1970. Manipulation of reservoir waters for improved quality and fish population response. Res. Rep. 62, Dep. of Nat. Resour. Madison, Wis. 23 p.

WIRTH, T. L., S. A. SMITH, and D. R. KNAUER
In preparation. Aeration as a lake management technique: a summary report. Inland Lake Demonstr. Proj., Upper Great Lakes Reg. Comm. Madison, Wis.

WISCONSIN DEPARTMENT OF NATURAL RESOURCES and UNIVERSITY OF WISCONSIN EXTENSION
1967. Wisconsin's shoreland protection ordinance. Madison, Wis. 78 p.

WOLLITZ, R. F.
1962. Effects of certain commercial fish toxicants on the limnology of three cold-water ponds, Montana. Proc. Mont. Acad. of Sci. 22:54-81.

WOMACK, J. D., J. E. BURDKICK, III and F. C. LARSON
1973. Impact of sewage treatment modifications on water quality of a reservoir. Water Resour. Bull. 9:100-115.

WOOD, R. B. and C. E. GIBSON
1972. Eutrophication and Lough Neagh. Water Res. 1:173-187.

WOOD, M. L. and L. E. LEACH
1969. Current research on reservoir destratification. Tech. Rep. No. 20, Proc. Ann. Environ. and Water Resour. Eng. Conf. 8:71-86. Nashville, Tenn.

WOOD, R. and D. W. PFITZER
1960. Some effects of water-level fluctuations on the fisheries of large impoundments, pp. 118-138. *In:* International union for conservation of nature and natural resources, soil and water conservation, vol. IV, theme 1. Brussels, Belgium.

WOODS, D. E.
1961. The effects of compressed air on winter oxygen levels in a fertile southern Minnesota lake. Minn. Fish and Game, Invest. Rep. No. 230, Invest. Fish. Ser. No. 3, pp. 51-62.

WUNDERLICH, W. E.
1938. Mechanical hyacinth destruction. Mil. Eng. 30:5-10.
1966. Aquatic vegetation control operations in Louisiana. Proc. South. Weed Control Conf. 19:450-452.

WYATT, H. N. and H. D. ZELLER
1962. Fish population dynamics following a selective shad kill. Proc. Ann. Conf., Assoc. Game and Fish Comm. 16:411-418.

YAKSICH, S. M. and M. W. TENNEY
1972. The impact and control of pollutionary releases from bottom muds of eutrophic lakes. Presented at the 45th Ann. Conf. of the Water Pollut. Control Fed. Atlanta, Ga.

YANGGEN, D. A.
1971. Wisconsin's shoreland protection program. *In:* Environmental quality and water development. U.S. Natl. Water Comm., XIX-1-49.

YARISH, W. and J. R. ALLAN
1971. Control of rooted submergent aquatic vegetation on Lake Wabanum and Lake Isle, Edmonton, Alberta. Res. Rep. Can. Weed Comm., West. Sec. 410 p.

YEO, R. R.
1970. Dissipation of endothal and effects on aquatic weeds and fish. Weed Sci. 18(2):282-284.
1971. Status of slender spikerush for controlling certain rooted aquatic weeds. Abstract. Meet. Weed Sci. Soc. of Amer., p. 32. Dallas, Texas.

YOUNG, R. L.
1970. Above Lake Needwood. Trends 7(1):17-20.

YOUNGBERG, C. T., P. C. KLINGEMAN, M. E. HARWARD, G. H. SIMONSON, D. RAI, D. W. LARSON, H. K. PHINNEY, and J. R. BELL
1971. Hills Creek Reservoir turbidity study. Water Resour. Res. Inst. and Dep. of Soil Sci., Oreg. State Univ., Corvallis, Oreg. 252 p.

YOUNGER, R.E.
1958. A preliminary report on controlling aquatic vegetation in New Jersey with KURON. Reprint from Down to Earth, Spring issue.

YOUNT, J. D. and R. A. CROSSMAN
1970. Eutrophication control by plant harvesting. Water Pollut. Control Fed. 42(5):R173-R183.

ZAR, H. (CHAIRMAN)
1972. Report of the Phosphorus Technical Committee to the Lake Michigan Enforcement Conference.

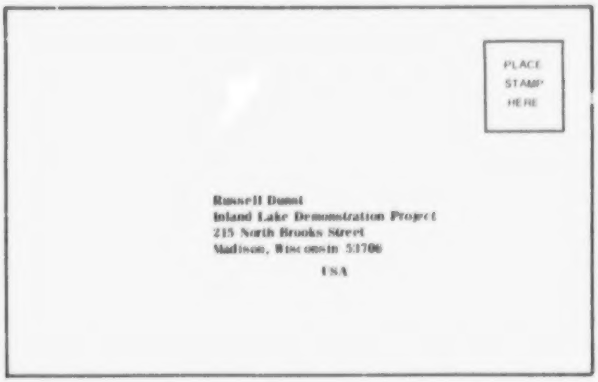
ZEIGER, C. F.
1967. Biological control of alligator-weed with *Agasicles* n. sp. in Florida. Proc. South. Weed Conf. 20:299-303.

ZELLER, H. D. and H. N. WYATT
1967. Selective shad removal in southern reservoirs, pp. 405-414. *In:* Reservoir fish. resour. symp. Amer. Fish. Soc. Athens, Ga.

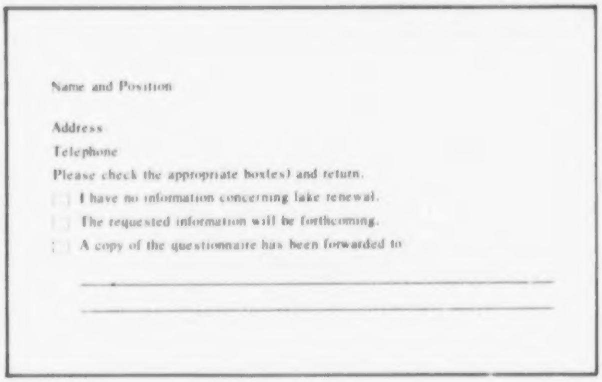
ZETTLER, F. W. and T. E. FREEMAN
1972. Plant pathogens as biocontrols of aquatic plants. Ann. Review of Phytopathol. 10:455-470.

APPENDIX

A: QUESTIONNAIRE


PLACE
STAMP
HERE

Russell Dunst
Inland Lake Demonstration Project
215 North Brooks Street
Madison, Wisconsin 53706
USA


Name and Position

Address

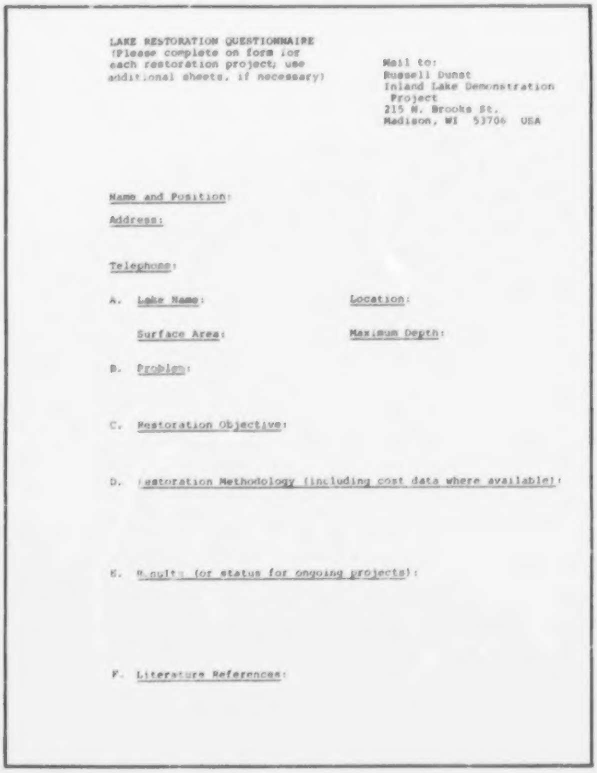
Telephone

Please check the appropriate box(es) and return.

☐ I have no information concerning lake renewal.

☐ The requested information will be forthcoming.

☐ A copy of the questionnaire has been forwarded to


LAKE RESTORATION QUESTIONNAIRE
(Please complete on form for
each restoration project; use
additional sheets, if necessary)

Mail to:
Russell Dunst
Inland Lake Demonstration
Project
215 N. Brooks St.
Madison, WI 53706 USA

Name and Position:

Address:

Telephone:

A. Lake Name: Location:

Surface Area: Maximum Depth:

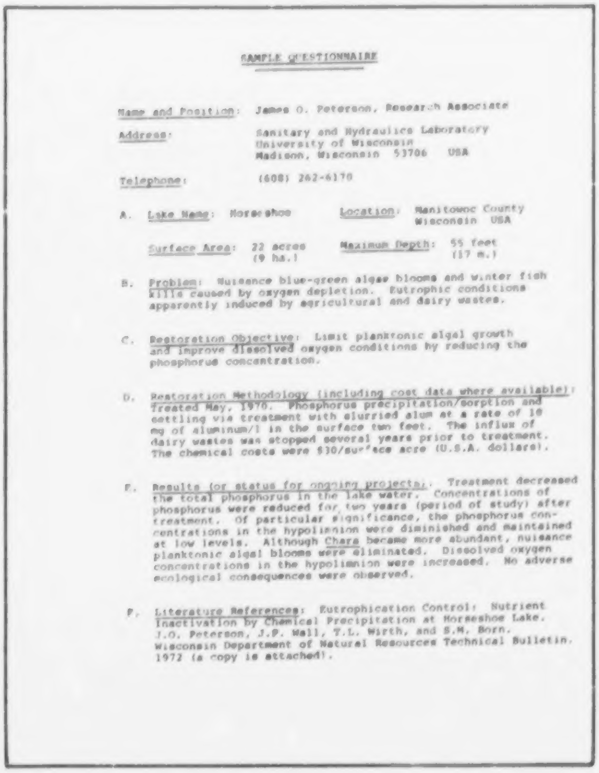
B. Problem:

C. Restoration Objective:

D. Restoration Methodology (including cost data where available):

E. Results (or status for ongoing projects):

F. Literature References:


SAMPLE QUESTIONNAIRE

Name and Position: James O. Peterson, Research Associate

Address:
Sanitary and Hydraulics Laboratory
University of Wisconsin
Madison, Wisconsin 53706 USA

Telephone: (608) 262-6170

A. Lake Name: Horseshoe Location: Manitowoc County Wisconsin USA

Surface Area: 22 acres (9 ha.) Maximum Depth: 55 feet (17 m.)

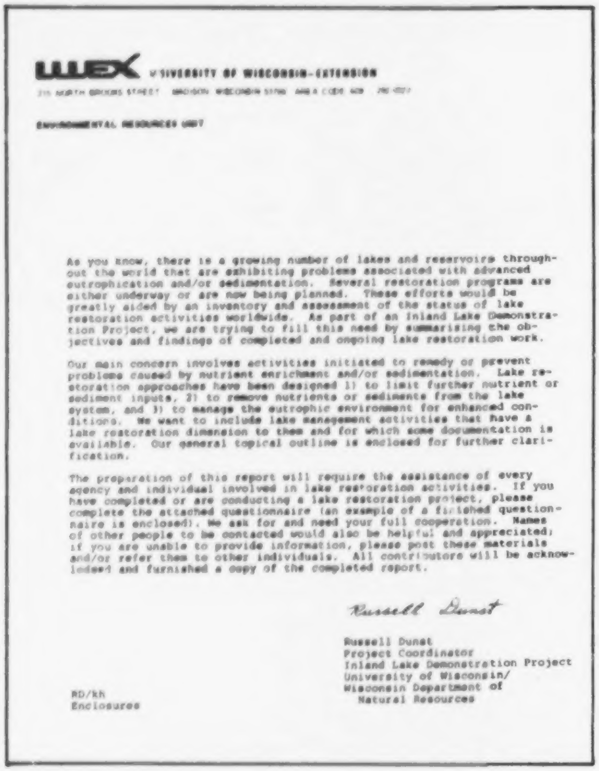
B. Problem: Nuisance blue-green algae blooms and winter fish kills caused by oxygen depletion. Eutrophic conditions apparently induced by agricultural and dairy wastes.

C. Restoration Objective: Limit planktonic algal growth and improve dissolved oxygen conditions by reducing the phosphorus concentration.

D. Restoration Methodology (including cost data where available): Treated May, 1970. Phosphorus precipitation/sorption and settling via treatment with slurried alum at a rate of 10 mg of aluminum/l in the surface two feet. The influx of dairy wastes was stopped several years prior to treatment. The chemical costs were $30/surface acre (U.S.A. dollars).

E. Results (or status for ongoing projects): Treatment decreased the total phosphorus in the lake water. Concentrations of phosphorus were reduced for two years (period of study) after treatment. Of particular significance, the phosphorus concentrations in the hypolimnion were diminished and maintained at low levels. Although Chara became more abundant, nuisance planktonic algal blooms were eliminated. Dissolved oxygen concentrations in the hypolimnion were increased. No adverse ecological consequences were observed.

F. Literature References: Eutrophication Control: Nutrient Inactivation by Chemical Precipitation at Horseshoe Lake. J.O. Peterson, J.P. Wall, T.L. Wirth, and S.M. Born. Wisconsin Department of Natural Resources Technical Bulletin. 1972 (a copy is attached).



UWEX UNIVERSITY OF WISCONSIN-EXTENSION
215 NORTH BROOKS STREET MADISON WISCONSIN 53706 AREA CODE 608 [illegible]

ENVIRONMENTAL RESOURCES UNIT

As you know, there is a growing number of lakes and reservoirs throughout the world that are exhibiting problems associated with advanced eutrophication and/or sedimentation. Several restoration programs are either underway or are now being planned. These efforts would be greatly aided by an inventory and assessment of the status of lake restoration activities worldwide. As part of an Inland Lake Demonstration Project, we are trying to fill this need by summarising the objectives and findings of completed and ongoing lake restoration work.

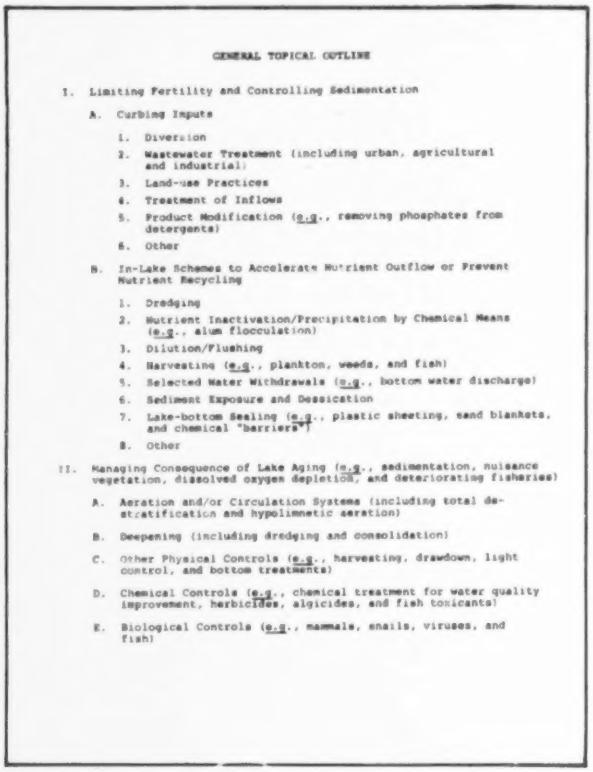
Our main concern involves activities initiated to remedy or prevent problems caused by nutrient enrichment and/or sedimentation. Lake restoration approaches have been designed 1) to limit further nutrient or sediment inputs, 2) to remove nutrients or sediments from the lake system, and 3) to manage the eutrophic environment for enhanced conditions. We want to include lake management activities that have a lake restoration dimension to them and for which some documentation is available. Our general topical outline is enclosed for further clarification.

The preparation of this report will require the assistance of every agency and individual involved in lake restoration activities. If you have completed or are conducting a lake restoration project, please complete the attached questionnaire (an example of a finished questionnaire is enclosed). We ask for and need your full cooperation. Names of other people to be contacted would also be helpful and appreciated; if you are unable to provide information, please post these materials and/or refer them to other individuals. All contributors will be acknowledged and furnished a copy of the completed report.

Russell Dunst

Russell Dunst
Project Coordinator
Inland Lake Demonstration Project
University of Wisconsin/
Wisconsin Department of
Natural Resources

RD/kh
Enclosures



GENERAL TOPICAL OUTLINE

I. Limiting Fertility and Controlling Sedimentation
    A. Curbing Inputs
        1. Diversion
        2. Wastewater Treatment (including urban, agricultural and industrial)
        3. Land-use Practices
        4. Treatment of Inflows
        5. Product Modification (e.g., removing phosphates from detergents)
        6. Other
    B. In-Lake Schemes to Accelerate Nutrient Outflow or Prevent Nutrient Recycling
        1. Dredging
        2. Nutrient Inactivation/Precipitation by Chemical Means (e.g., alum flocculation)
        3. Dilution/Flushing
        4. Harvesting (e.g., plankton, weeds, and fish)
        5. Selected Water Withdrawals (e.g., bottom water discharge)
        6. Sediment Exposure and Dessication
        7. Lake-bottom Sealing (e.g., plastic sheeting, sand blankets, and chemical "barriers")
        8. Other

II. Managing Consequence of Lake Aging (e.g., sedimentation, nuisance vegetation, dissolved oxygen depletion, and deteriorating fisheries)
    A. Aeration and/or Circulation Systems (including total destratification and hypolimnetic aeration)
    B. Deepening (including dredging and consolidation)
    C. Other Physical Controls (e.g., harvesting, drawdown, light control, and bottom treatments)
    D. Chemical Controls (e.g., chemical treatment for water quality improvement, herbicides, algicides, and fish toxicants)
    E. Biological Controls (e.g., mammals, snails, viruses, and fish)

B: LAKE RESTORATION INVENTORY—NEWS RELEASE

Your Help Is Needed For An Inventory Of Lake Restoration Experiences

An inventory and assessment of the status of lake restoration activities worldwide has been initiated by the Inland Lake Demonstration Project, a joint venture of the University of Wisconsin and the Wisconsin Department of Natural Resources. The final report (due in June, 1973) will include a review of lake restoration experiences and a comprehensive bibliography. Future lake restoration programs and related research should be greatly aided by this report.

Preparation of the report will require the assistance of every agency and individual involved in lake restoration. Information is desired concerning any activity initiated to remedy or prevent problems caused by nutrient enrichment and/or sedimentation of a lake or reservoir; this activity may be in the area of research or management. Anyone acquainted with a past or current lake restoration project is requested to contact Russell Dunst, Inland Lake Demonstration Project, 215 N. Brooks Street, Madison, WI 53706 U.S.A. (telephone: 608-262-3454) for further details. All contributors will be acknowledged and furnished a copy of the completed report.

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ACKNOWLEDGMENTS

This report required the cooperation of many people. We sincerely thank all those who voluntarily furnished information about specific lake restoration activities. We are also indebted to numerous individuals who facilitated project execution with helpful advice. The final manuscript was improved by many valuable and constructive (sometimes provocative) review comments: Special thanks are extended to N. G. Benson, P. L. Brezonik, M. G. Browman, W. T. Edmondson, C. R. Goldman, R. F. Harris, A. D. Hasler, R. M. Jenkins, L. E. Keup, R. E. Lennon, K. M. Mackenthun, K. W. Malueg, C. H. Wahtola, Jr. and T. D. Wright. We hope that those who assisted in this endeavor, and readers in general, find this document of use in their work.

Partial funding for this project was provided by the U. S. Environmental Protection Agency, Office of Research and Development, Eutrophication and Lake Restoration Branch, Grant No. R802242.

The contents of this report do not necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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Translation of German languages materials courtesy of Jerry Reich.

Edited by Ruth L. Hine and William Dyer.

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